MINING, PROCESSING, AND COSTS--
IDAHO ALMADEN MERCURY MINE, WASHINGTON COUNTY, IDAHO

BY MARGARET R. LICKES

* * * * * * * * * **Information Circular 7800**

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by

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SUMMARY

Mercury was produced originally at the Idaho Almaden mine from 1939 to 1942. When the mine was shut down, more than 100,000 tons of ore, containing from 2.5 to 3 pounds of mercury per ton, was known to be adjacent to old workings but had been considered too low grade for commercial operation. Later, detailed, systematic exploration by Rare Metals Corporation of America increased and delimited enough minable reserves for further operation to be foreseen for several years. The average grade of the ore is estimated at slightly more than 3.5 pounds of mercury per ton. Open-pit mining and installation of the largest rotary kiln in the United States furnacing mercury ore have made possible profitable exploitation of these reserves (fig. 1).

The bulk of the exploration was by percussion drilling, although some diamond drilling was done to check the results. When enough reserves were indicated to assure a successful operation, stripping and plant construction were started simultaneously. Figure 2 is a general view of the plant.

The ore bodies, although irregular in size, shape, and grade and covered by essentially barren cap rock, are amenable to low-cost, trackless, open-pit mining. Development consists of stripping the overburden and removing barren cap rock.

Ore is being mined at approximately 5,000 tons per month and treated in a 175-ton-per-day furnacing plant.

INTRODUCTION

This is one of a series of reports being published by the Federal Bureau of Mines on mining methods, performance, and costs at individual mines in the United States. The primary purpose of these papers is to promote development and conservation of our mineral resources by disseminating technological information on methods, practices, and results that may be applied to the engineering analysis and solution of mining problems.

It is hoped that the program will (1) promote efficiency in mining operations, (2) assist operators and engineers in evaluating and developing new mineral deposits, (3) provide data for engineering curricula in mining schools, (4) provide research agencies of the Government with reports for use in developing a realistic mineral policy, and (5) furnish performance and cost data for mining-engineering textbooks and handbooks.

This report discusses the open-pit mining operations, furnacing plant and costs at the Idaho Almaden mercury mine, Rare Metals Corporation of America, near Weiser, Idaho (fig. 3). It tells of a mine, long believed to contain reserves of mercury ore too low grade to be operated profitably, restored to production by detailed evaluation, careful planning, and application of low-cost open-pit mining.

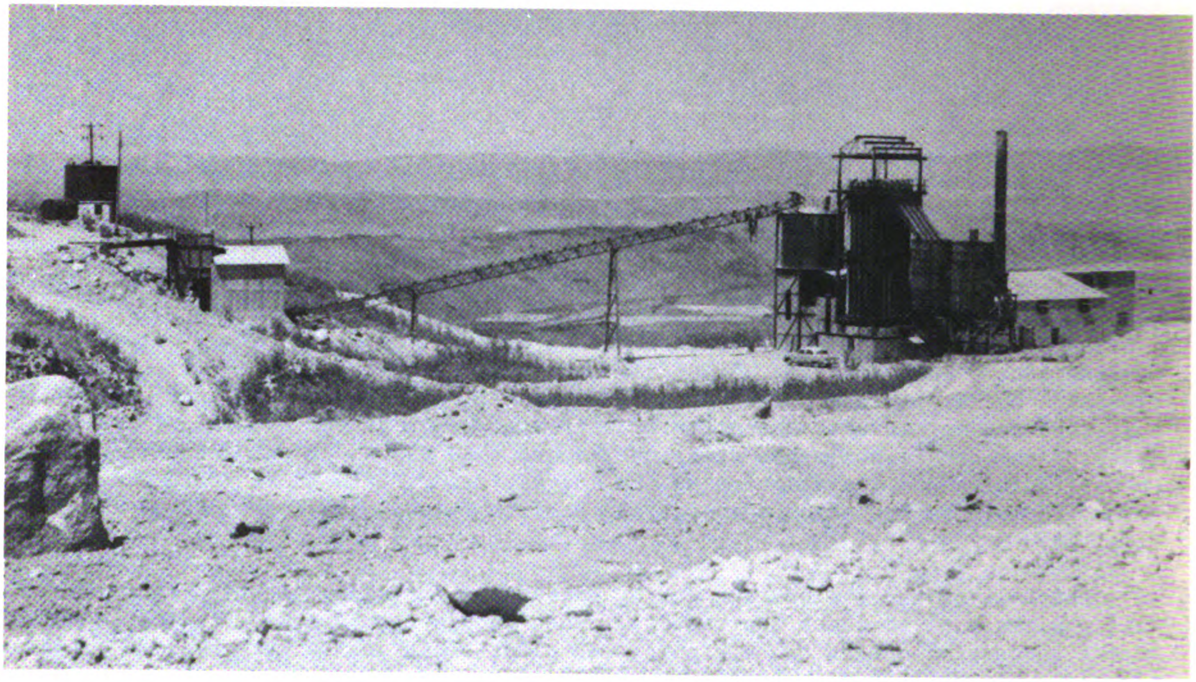

Figure 1. - Furnacing plant. Blending apron and crushing plant at left, oil tanks directly beyond.

(Courtesy, Rare Metals Corporation of America.)

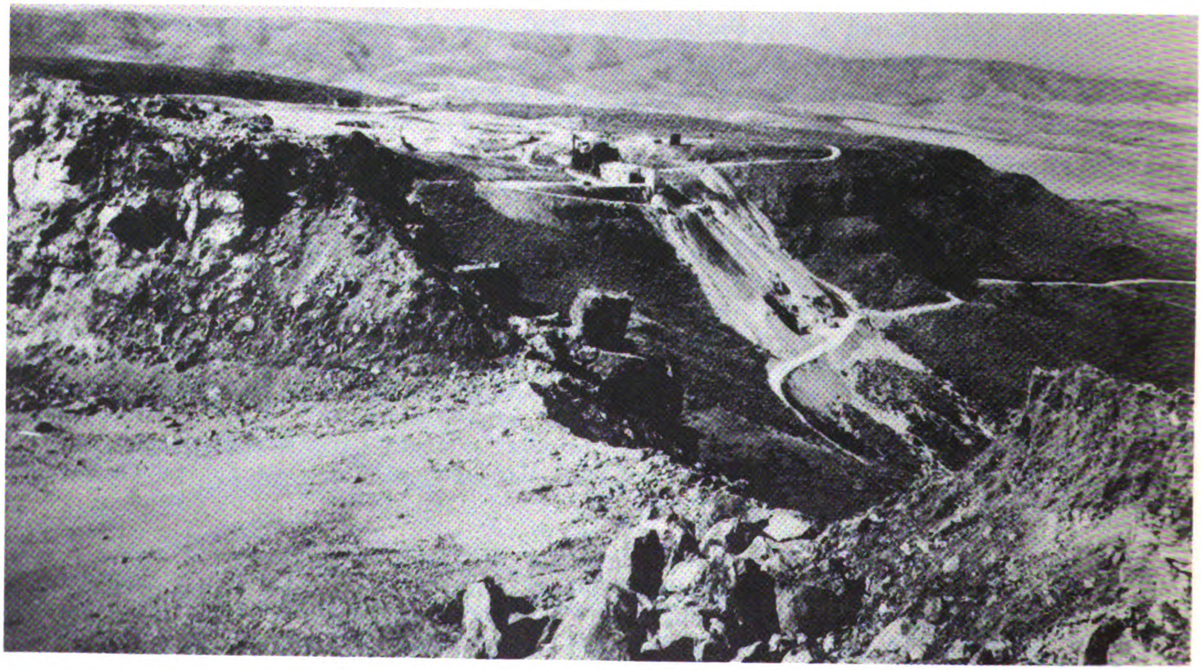

Figure 2. - General view. "D" pit in foreground; "A" pit left of plant.

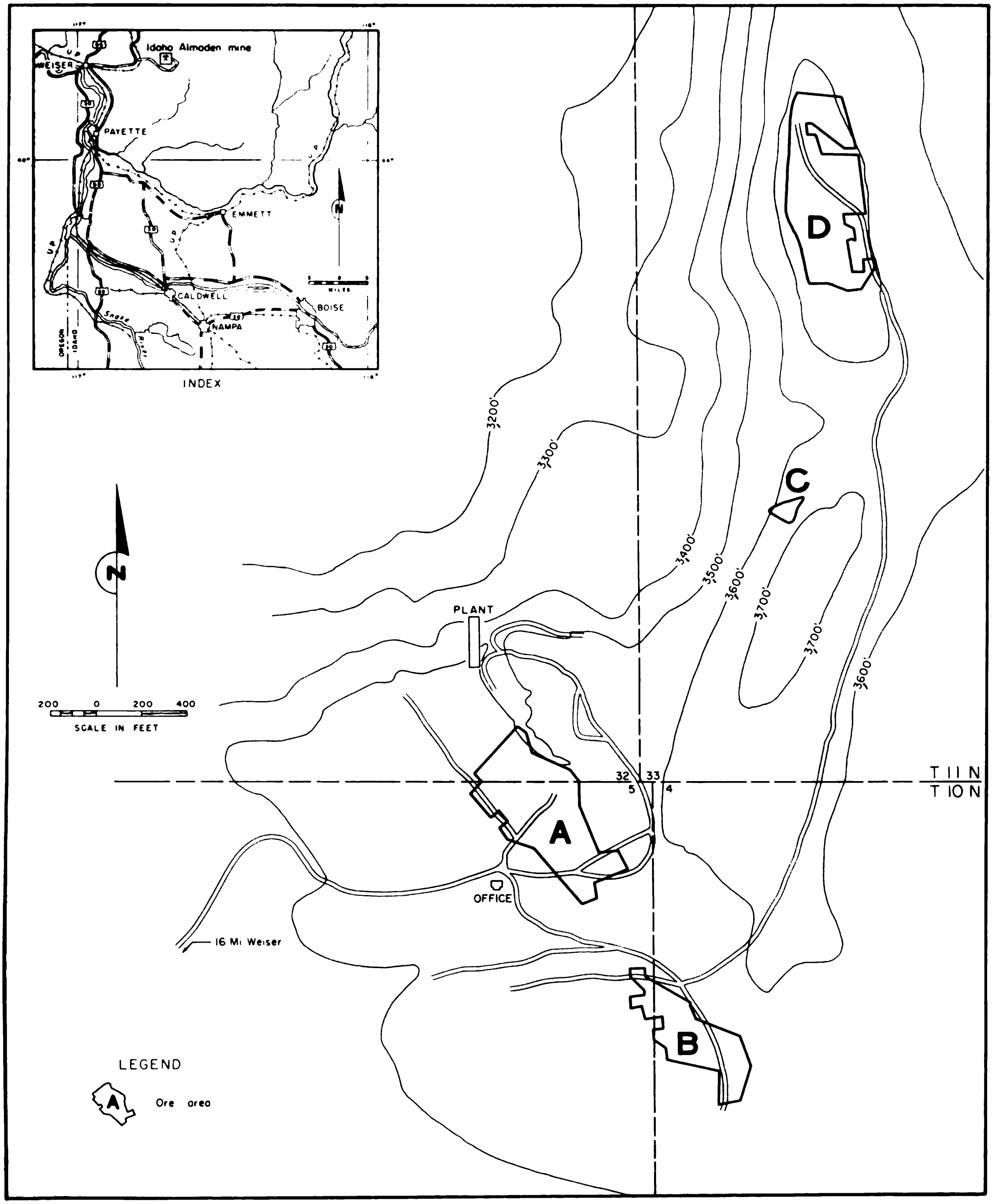

Figure 3. - Location of Idaho Almaden mine.

ACKNOWLEDGMENTS

Sincere appreciation is extended to Mitchell H. Kline, vice president and assistant general manager, Rare Metals Corporation of America, for his cooperation in gathering material for this paper and permitting it to be published.

Grateful acknowledgment is made to E. J. Carlson, superintendent of the Northwest Division, John R. Reynolds, chief engineer, R. L. McConn, chief accountant, and James J. Snider, plant superintendent, who gave freely of their time and knowledge.

Most photographs and maps, furnished through courtesy of the Rare Metals Corp., were made or drawn by Stephen Odysseus, chief draftsman. Several photographs were furnished by the Mining World magazine.

Permission to publish statistics on the earlier operation of the property was kindly given by L. K. Requa, general manager of Idaho Almaden Mines, Inc.

LOCATION AND PROPERTY

The Idaho Almaden mine can be reached by traveling easterly from Weiser, Idaho, over 17 miles of paved and graveled highway. Weiser, a town of 4,000, is on the Idaho-Oregon boundary in Washington County, Idaho, at the confluence of the Weiser and Snake Rivers. It is served by the Union Pacific Railroad and by United States Highways Nos. 95 and 30N.

The property consists of 40 acres of deeded land and 1 patented and 32 unpatented claims in secs. 32 and 33, T. 11 N., R. 3 W., and secs. 4 and 5, T. 10 N., R. 3 W. The Rare Metals Corporation of America holds these lands under lease, with option to purchase from the owners. The mine and furnacing plant are on Nutmeg Mountain, which overlooks the valley of Bear Creek, a tributary of the Weiser River.

The region is semiarid, with a temperature range from minus 18° in the winter to as high as 100° in the summer; some snow falls in winter. Only sparse, desert-type vegetation grows without irrigation.

HISTORY

In 1936 Harry Brown discovered cinnabar mineralization on Nutmeg Mountain. The following summer he staked 17 claims and named the property the Osa Anna.

Later the same year, L. K. Requa and associates leased the claims (then called the Nutmeg mine) and formed the Idaho Almaden Mines Corp. to explore and develop them. Further staking increased the area controlled by the corporation to about 500 acres.

The deposit was explored by trenching, sinking shallow shafts, and drilling. Exploration indicated enough reserves to warrant construction of a 50-ton reduction plant. The first production of mercury was made in June 1939. Most mining was done by open pit and the ore was mucked, sorted, and trammed by hand. Where the ratio of cap rock to ore was 2:1 or more, mining was carried underground, and ore was extracted by room-and-pillar stoping. In wide widths of ore a system of square-set timbering was necessary; otherwise, stulls and headboards sufficed.2/ Ore was mined selectively and loaded mechanically by slusher.

2/ Requa, L. K., Idaho Almaden: Mining World, vol. 3, No. 7, July 1941, pp. 33-37.

The ore was furnaced in an oil-fired, rotary kiln, 3 feet in diameter by 48 feet in length; mercury was condensed in a set of 10-gage steel pipes, and the gases were cleaned as they passed through redwood-stave tanks to a stave stack. Electric power was furnished by a 20-kw. diesel generator.

According to Requa, for the entire early operation (1939-42), an average of 5.67 pounds of mercury was recovered per ton of ore, although monthly averages were as high as 12.5 pounds per ton. Recovery was estimated at about 94 percent of the contained mercury.

About 4 pounds of mercury per ton was considered the cutoff grade; when the ore averaged this minimum, the operation was shut down (December 1942), and the plant was dismantled and removed.

Production during the early operation is given in table 1.

TABLE 1. - Production, Idaho Almaden Mines Corp., 1939-42

Furnished by L. K. Requa

Year	Ore mined, short tons	Mercury recovered, flasks	Mercury recovered per ton, pounds
1939	8,451	1,041	9.36
1940	14,191	1,097	5.87
1941	15,705	991	4.80
1942	14,726	830	4.28
Total	53,073	3,959	-
Weighted average			5.67

GEOLOGY

General

The Idaho Almaden mercury deposit occurs in the Miocene Payette formation on the crest of one of a series of parallel, broad-crested anticlines trending northwesterly.[3] The formation is of lacustrine and terrestrial origin and consists of well-consolidated and well-stratified ash, carbonaceous shale, and sandstone, interbedded with Columbia River basalt.

The Payette usually is overlain by the upper series of Columbia River basalt and in a few places by the Owyhee rhyolite.[4] A short distance south and west of the deposit the basalt is overlain by the Idaho formation of Pliocene age.

The folded sediments in the area are disturbed by a series of major faults trending north-south and east-west. Minor faults cut diagonally across the major faults, strike nearly parallel to the anticlinal axis, and dip steeply. The ore is localized on the crest of the anticline in an area where flexures and faulting have produced a local structural depression.

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[3] Anderson, Alfred L., Geology of the Idaho Almaden Quicksilver Mine Near Weiser, Idaho: Idaho Bureau of Mines and Geol. Pamphlet 55, 1941, 9 pp.

[4] Kirkham, V. R. D., Revision of Payette and Idaho Formations: Jour. Geol., vol. 39, No. 3, 1931, pp. 193-239.

Mineralization

The ore mineral is cinnabar; the gangue minerals are opal, chalcedony, feldspar, and traces of pyrite. In most of the ore the cinnabar is finely divided and appears as a delicate pigment in which individual grains are distinguishable only under the microscope. The outcrop for a long time escaped detection, because cinnabar fades to a dull blue-black when exposed to air; the characteristic red color is seen only on fresh surfaces.

Mineralization was preceded by silicification of a wide area, and the sandstone and shale country rock has been altered in varying degrees. Opalite was deposited in at least two distinct periods; the first was barren, and the second had a minor quantity of cinnabar. Chalcedony was formed after the opalite, and deposition of the major part of the ore occurred last.[5]

A flat bed of siliceous sinter, relatively impermeable, somewhat brittle, and resembling a soft shale, acted as a cap rock to localize mineralization. Generally, it determines the upper limit of the ore. The ore minerals impregnated the permeable sandstone and to some extent the shale. The deposit appears to have formed a broad, irregular hood over the depressed part of the crest of the anticline.

Cinnabar is widespread throughout the silicified rocks. Some of it is diffused through the later opalite, but most of it is in scattered grains, granular aggregates, and minute veinlets; in relatively rich ore cinnabar is disseminated on both sides of these tiny veinlets. Some of the highest grades of ore are near the center of mineralization, where it occurs in a gangue of white kaolin.

Generally, mineralization is irregular. All variations in the ratio of chalcedony to opalite are found. In places the cinnabar occurs in more or less porous opalite and is absent in the chalcedony; nearby it may be present in the dense chaldony and absent in the opalite. Because of this characteristic of the ore, there is no completely barren ground in the mineralized mass; mining dilution is by low-grade mineralized rock.

SAMPLING

The key to the successful operation of the Idaho Almaden mine is sampling. Boundaries of the ore bodies are determined by assaying, so all holes drilled for exploration, development, and mining are sampled completely. One-half-pound splits of cuttings from each 5-foot interval of every drill hole are assayed.

Exploration and development drilling, totaling 17,452 feet, plus 85 channel samples, required 4,666 assays and outlined 4 ore bodies.

Production blasting is controlled by assays of the blasthole drill cuttings; the area to be mined is selectively blasted according to assay results. Ore and waste are blasted separately.

Head feed and calcine are sampled hourly. Each is composited daily and a portion assayed.

In addition to daily assaying at the mine laboratory check samples of drill cuttings and head and tail plant samples are sent periodically to the Rare Metals custom laboratory at Murray, Utah, and occasionally to other custom assayers.

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[5] Work cited in footnote 2, p. 4.

THE MINE

Exploration

Before Rare Metals began its operation, an ore body, containing an estimated 100,000 tons of ore (2 to 3 pounds of mercury per ton), was believed to exist adjacent to and underneath the old workings. Additional mineralized areas, one visually evident in a steep hillside adjoining the mine area and another that had been explored by shallow trenches following the early operation, were attractive exploration targets.

Percussion wagon drilling was used for exploration. A chain-feed, wagon-type, percussion drill and a 380-c. f. m. compressor were mounted on a halftrack to make a self-contained, mobile drill rig (fig. 4). Diamond drilling was done to check the results of percussion drilling and to determine the physical characteristics of the rock.

Drilling was begun in the area of the old workings. Holes were drilled in a grid pattern on approximately 25-foot centers in rows 50 to 75 feet apart, the spacing depending on the terrain and accessibility (fig. 5). Sectional, 1-inch hexagonal steel, in 8-foot joints, equipped with 2-inch carbide-insert bits, was used. Maximum depth of holes was 100 feet; average depth, 40 feet; average daily footage drilled, 200 feet. More than 500 wagon-drill holes were completed; they were checked by 68 diamond-drill holes.

Originally, drill cuttings were caught under suction; however, this method was found to be less practical than cutting a hole in the bottom of a square tub and putting the tub over the hole collar. Later, a pasteboard box was substituted for the tub, and all exploration and blasthole cuttings now are caught in pasteboard boxes.

Percussion drilling generally was successful. Diamond-drilling results were disappointing; many holes were abandoned before completion, core recovery was poor, and the cost was excessive. One type of rock, consisting of angular to subrounded grains of quartz cemented by chalcedonic silica,6/ is so abrasive that the matrix of core bits was worn away and the diamonds were lost. One bit was ruined in 12 inches of drilling. This abrasive rock is brittle, however, and chips readily when percussion-drilled. About 40 carbide-insert bits were used without regrinding to drill 17,452 feet. The core checked the results of percussion drilling so well that coring was discontinued. Mining has confirmed the accuracy of the percussion-drill samples.

Four ore bodies for open-pit mining were outlined and designated A, B, C, and D (fig. 3). A is the extension of the mineralized body exploited in the old workings; B is the ore body that was indicated in a hillside adjoining the mine area to the south; C is a small body of high-grade cinnabar on the hill east of A; and D, almost due north of C, is the ore body indicated by shallow trenching following the early operation.

The A, B, and D ore bodies generally are blanketlike deposits that range in area to as much as 350,000 square feet and vary from 3 to 45 feet in thickness. C ore body occurs as fissure filling in a fractured zone and contains neither opalite nor chalcedony. During the early operation, C was mined from two short adit levels by small stopes from which several hundred tons was mined.

6/ Thin section described by R. R. Reid, Geol. Dept., College of Mines, Univ. of Idaho.

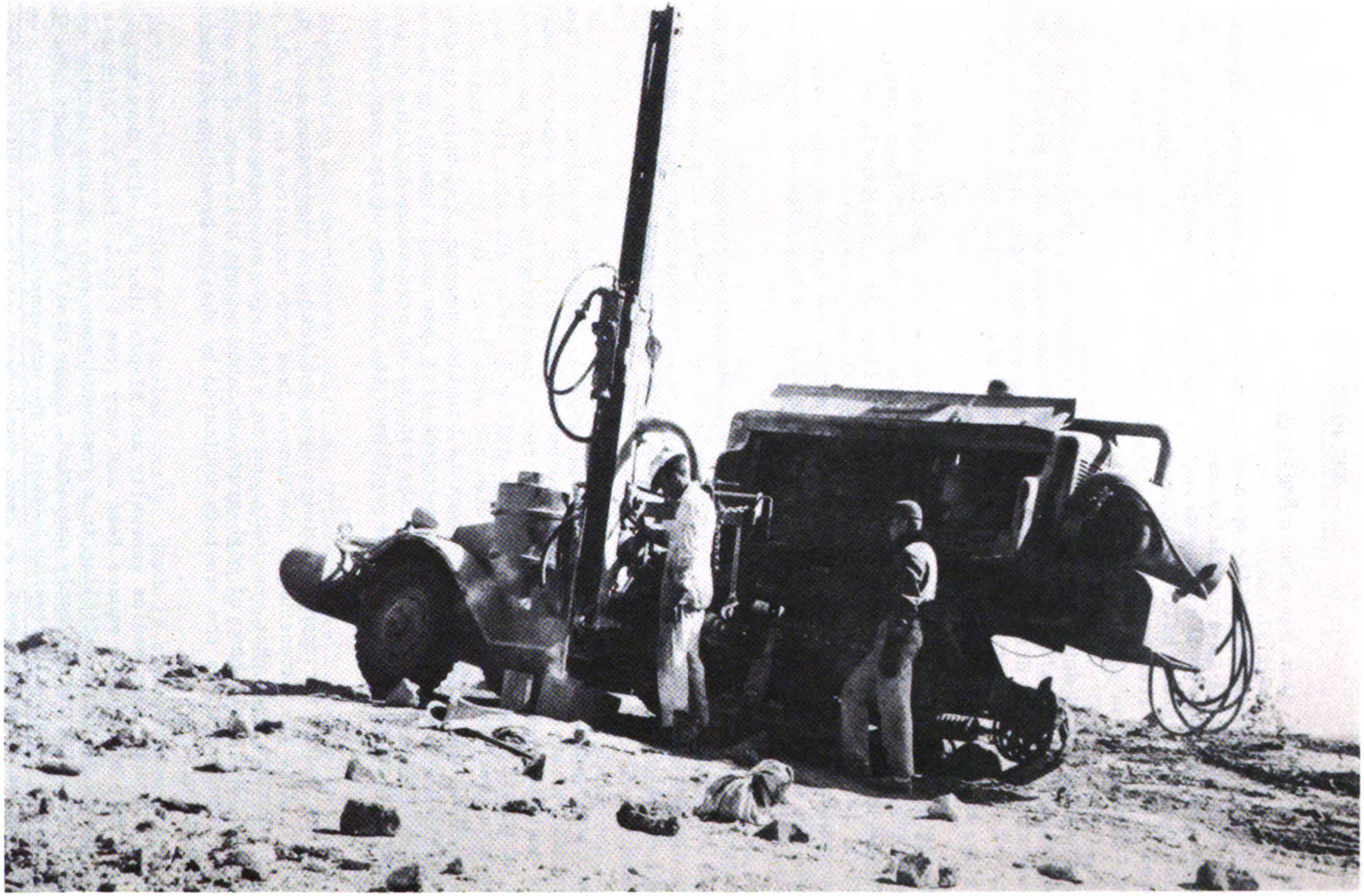

Figure 4. - Self-contained percussion drill rig. Cuttings being collected in pasteboard boxes.
(Courtesy, Rare Metals Corporation of America.)

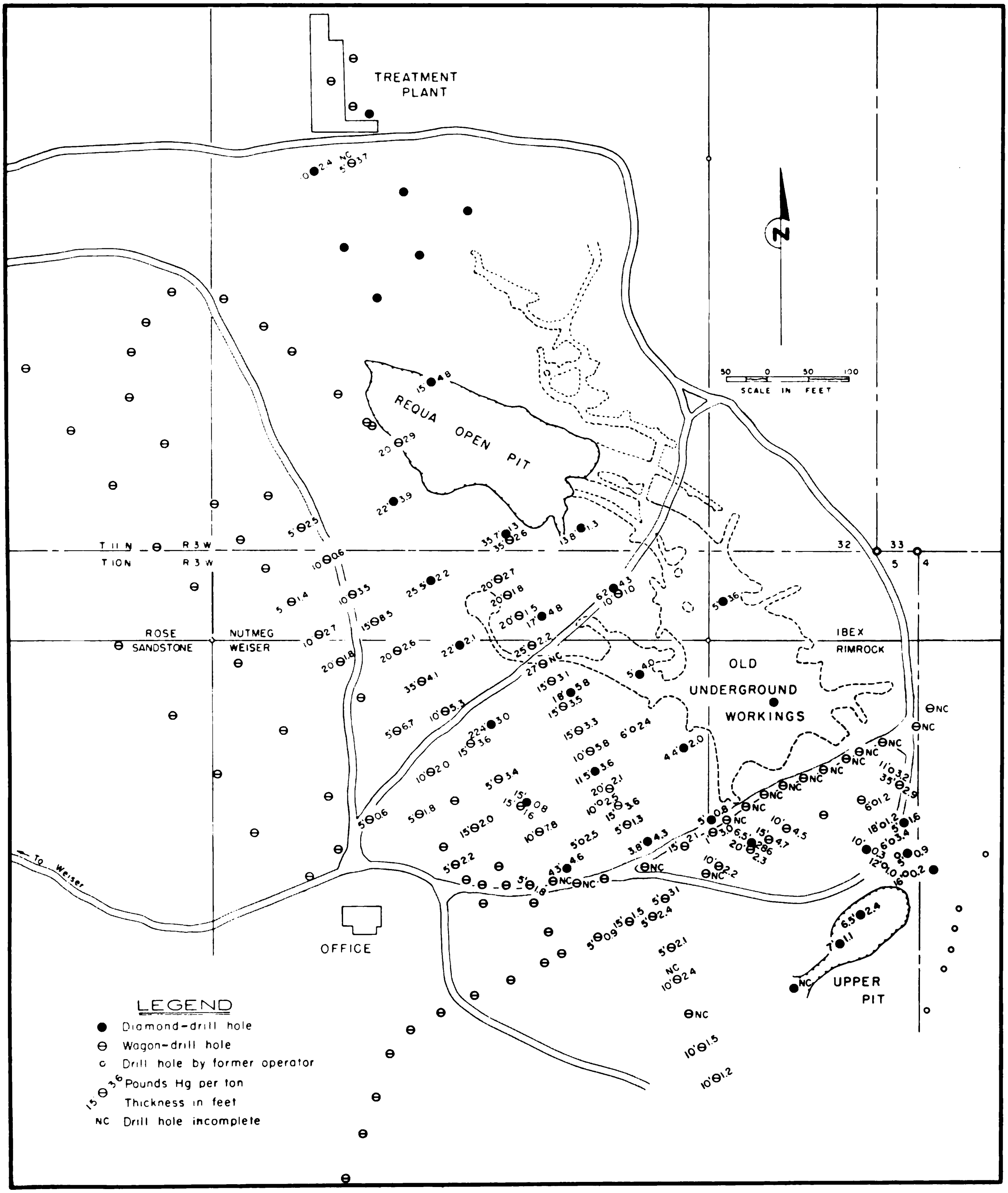

Figure 5. - Exploration drilling, "A" area.

Estimating reserves by a cross-sectional method was facilitated by grid-pattern drilling. The average grade of the ore section in each hole was established by weighting the assay of each ore sample by its length. The drill holes in each line drilled were weighted according to their spacing to give the average grade and thickness of the ore; the area of influence of each cross section was half the linear distance to the next section or to a known surface outcrop. The volume and grade of each ore body were determined by multiplying the surface area, measured by planimeter, by the average thickness and grade.

In converting volume to tonnage several specific-gravity determinations were made of representative ore from each of the ore bodies. The conversion factor varied slightly; that for ore bodies A and B was 14 cubic feet per ton and for C and D, 13 cubic feet per ton.

Total reserves, as of April 1, 1956, were estimated at slightly more than one-half million tons of ore, containing an average of 3.5 pounds of mercury per ton. Ore containing 2 pounds of mercury per ton is considered to be the ultimate cutoff grade of commercial ore when the plant has been amortized and the lease paid in full.

Reserves of A and D ore bodies comprise 79 percent of the total tonnage and 81 percent of the contained mercury. Because D ore body is estimated to contain an average of 1.25 pounds more mercury per ton than A, their relative positions are reversed in the two categories: A contains 43 percent and D 36 percent of the ore tonnage, and D contains 44 percent and A 37 percent of the contained mercury. Although C ore body is small, having less than 1 percent of the total tonnage, it is the highest grade and is estimated to contain almost 2 percent of the mercury.

Exploration is being continued to supplement the reserve tonnage. The drilling unit is utilized in further exploration when it is not being used for blasthole drilling. Holes are drilled away from known ore areas on 50-foot centers; in favorable locations spacing is narrowed to 25 feet.

For greater depth than is possible with percussion drilling, consideration is being given to churn drilling through the fractured, porous, upper horizon; installing casing, if necessary; then continuing by diamond drilling.

Development

Preparation for mining consisted of stripping the overburden and the major portion of the cap rock, which ranged from 0 to 30 feet in thickness and averaged 5-1/2 feet. It amounted to 1 ton for each 2.5 tons of ore estimated.

Initial stripping of overburden was done under contract, using large earth-moving equipment (fig. 6). In 1 month a total of 94,516 cubic yards was removed at a cost of 26.5 cents per cubic yard (figs. 7 and 8). This removed the bulk of the overburden from A, B, and D ore bodies; C is not amenable to stripping.

Directly in advance of mining, the remaining waste cap rock is removed. Ore boundaries are determined by assaying drill cuttings, and the cap rock is removed before the ore is blasted.

Waste disposal is no problem: Some rock is pushed over the cliff to rest on the steep hillside, and some is piled in barren areas. Large quantities of waste rock, as well as burned rock from processing, have been used in roadbuilding by the company and the county.

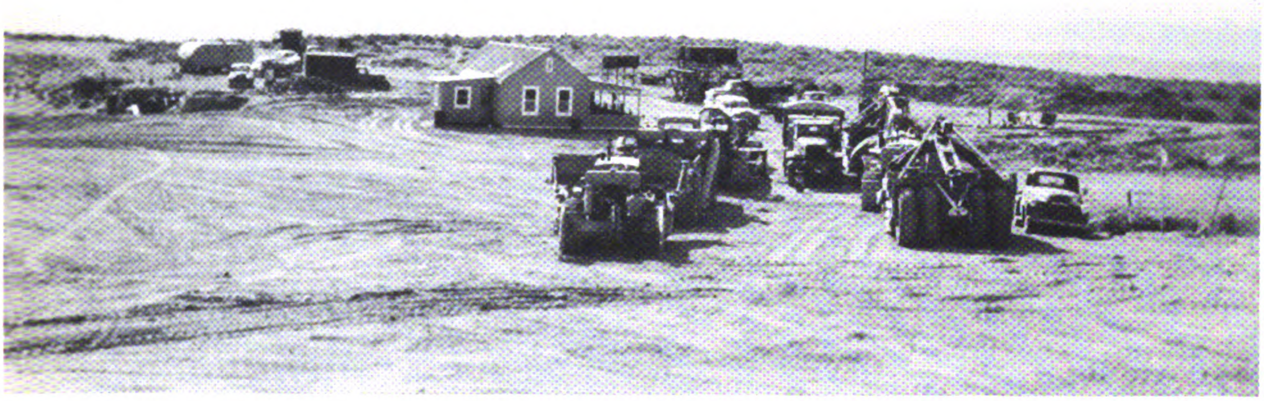

Figure 6. - Contract stripping equipment. *(Courtesy, Rare Metals Corporation of America.)*

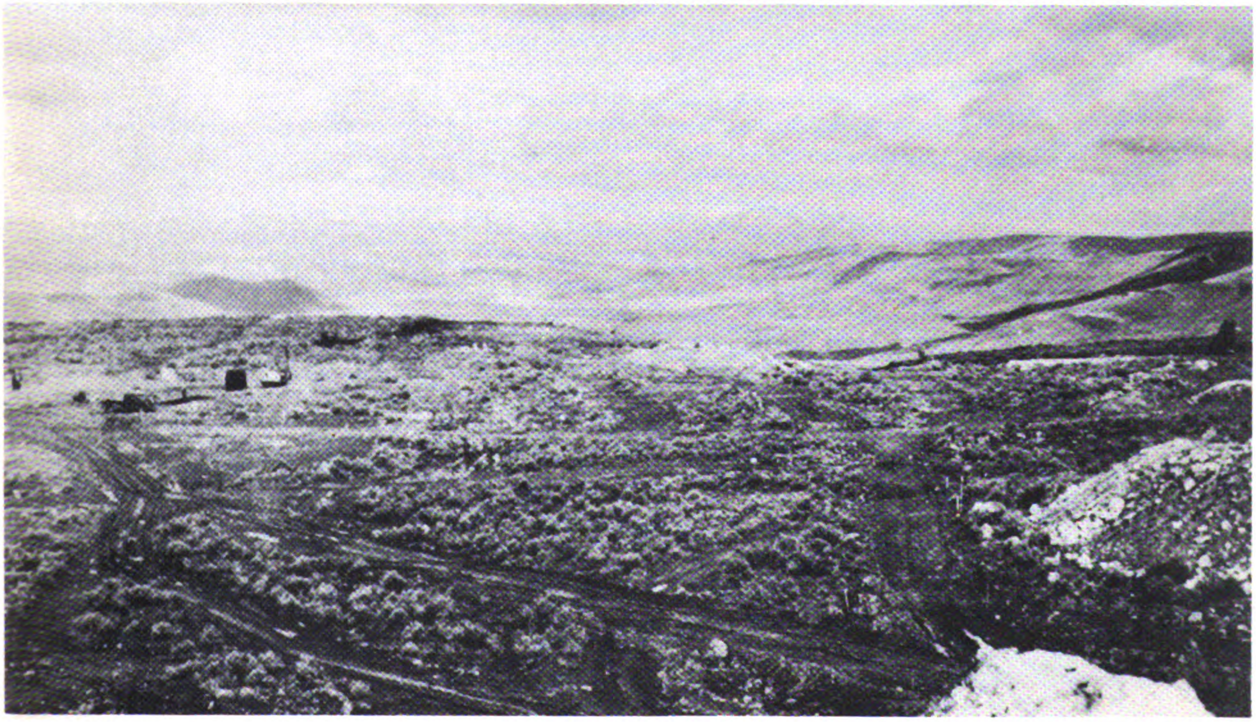

Figure 7. - "A" ore area before stripping. *(Courtesy, Rare Metals Corporation of America.)*

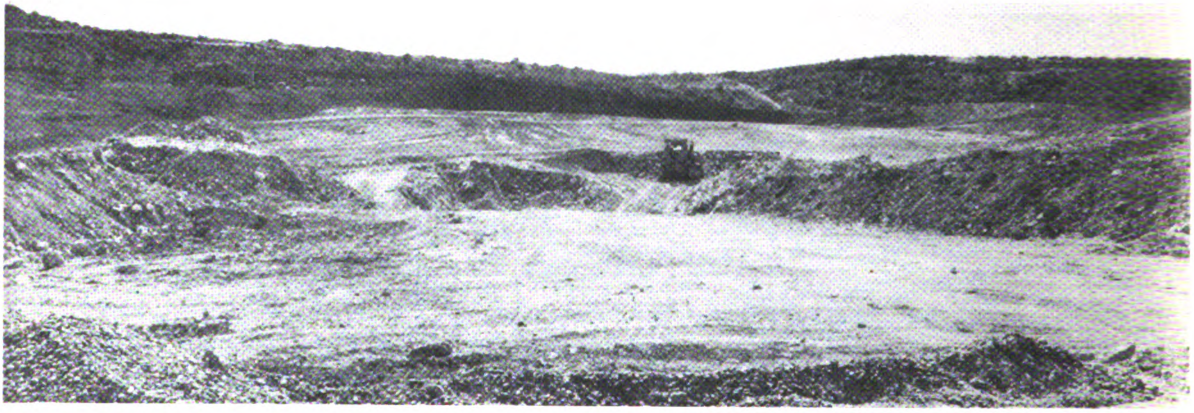

Figure 8. - "A" ore body after stripping. *(Courtesy, Mining World.)*

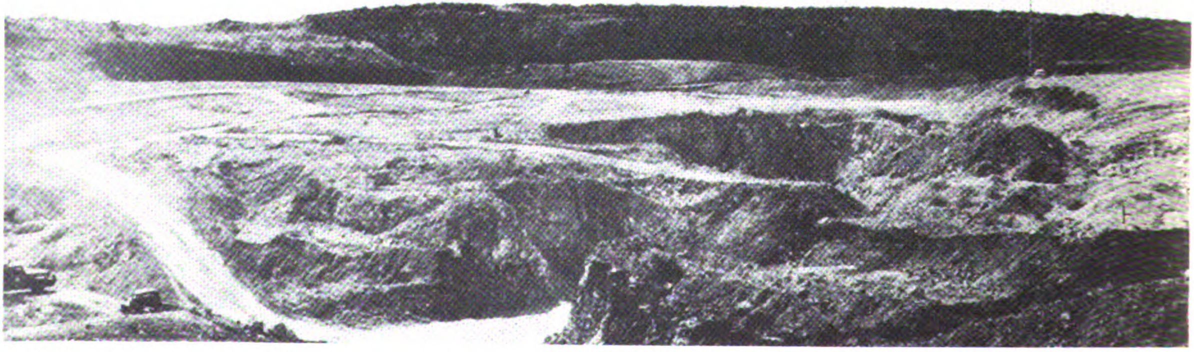

Figure 9. - "A" open pit. Taken from top of condensers. *(Courtesy, Rare Metals Corporation of America.)*

Exploitation

Blasthole drilling is done with the mobile percussion-drill rig, using the same tools as for exploration. Two-inch holes are drilled in a 6-foot grid pattern, then blasted selectively according to sample assays. Waste, if near the periphery of the pit, is left in place; if surrounded by ore, it is blasted after the ore has been mined.

Mining is carried forward in benches, which vary in height from 12 feet in D pit to 22 feet in A pit; the height of the bench depends on the terrain and depth of the ore (fig. 9).

Originally, blastholes were loaded with 40-percent Gelodyn stick powder (1 stick of 60-percent powder per hole for the primer) and blasted electrically, using 0 and Nos. 1 and 2 delay blasting caps. Flo-dyn bag powder No. 7, 60-percent strength, has been substituted for the 40-percent stick powder because of its easier and better loading qualities in ragged holes. An average of 50 holes is blasted per shot, breaking about 1,500 cubic yards, or between 2,000 and 2,500 tons. Explosive requirements average 0.4 pound per cubic yard.

Drill-steel and bit wear is low. Since mining was begun, regrinding two bits per blast is average; occasionally a steel is broken, averaging not more than one per month.

Very little secondary blasting is necessary, except in D pit. Ore in A and B pits generally breaks fine enough to be treated. In D pit, however, the ground breaks blocky, and several-ton sandstone boulders are left. Because the boulders break along fracture planes and contain ore only along these planes, they are blockhole drilled and blasted in the pit; the ore is saved and the remainder discarded. The amount of ore that is too large to crush without further blasting is negligible.

Ore is loaded with a crawler-mounted, 2-yard rocker shovel into 2-ton dump trucks (fig. 10). Two shovel loads are required to fill each truck. One shovel and two dump trucks supply the operation.

The truck haul is short - 200 yards from A pit, 1/4 mile from B pit, 1/2 mile from C pit, and 3/4 mile from D pit - to the blending apron beside the crushing plant. The maximum haulage grade is 6 percent. Each load is weighed en route to the coarse-ore bin or to the stockpile.

The blending apron is an 80- by 80-foot concrete slab with a storage capacity of more than 10,000 tons (fig. 11). It is a dual-purpose installation set beside the crusher hopper. As a surge platform, ore stored here permits a 5-day-per-week mining operation to supply a 7-day-per-week furnacing operation. As a grade-control platform, ore piled as mined from the separate pits can be fed according to grade. The average storage load on the apron is 500 to 1,000 tons. Although steam pipes are embedded in the apron as a precaution against freezing of the ore, no heating has been necessary.

Rock containing less than 2 pounds of mercury per ton is wasted or used for road ballast. Better grade rock (up to 2.5 pounds of mercury per ton) is sent to low-grade stockpiles for future treatment.

Pits A and D have supplied more than 80 percent of the ore mined. Table 2 shows the distribution of production.

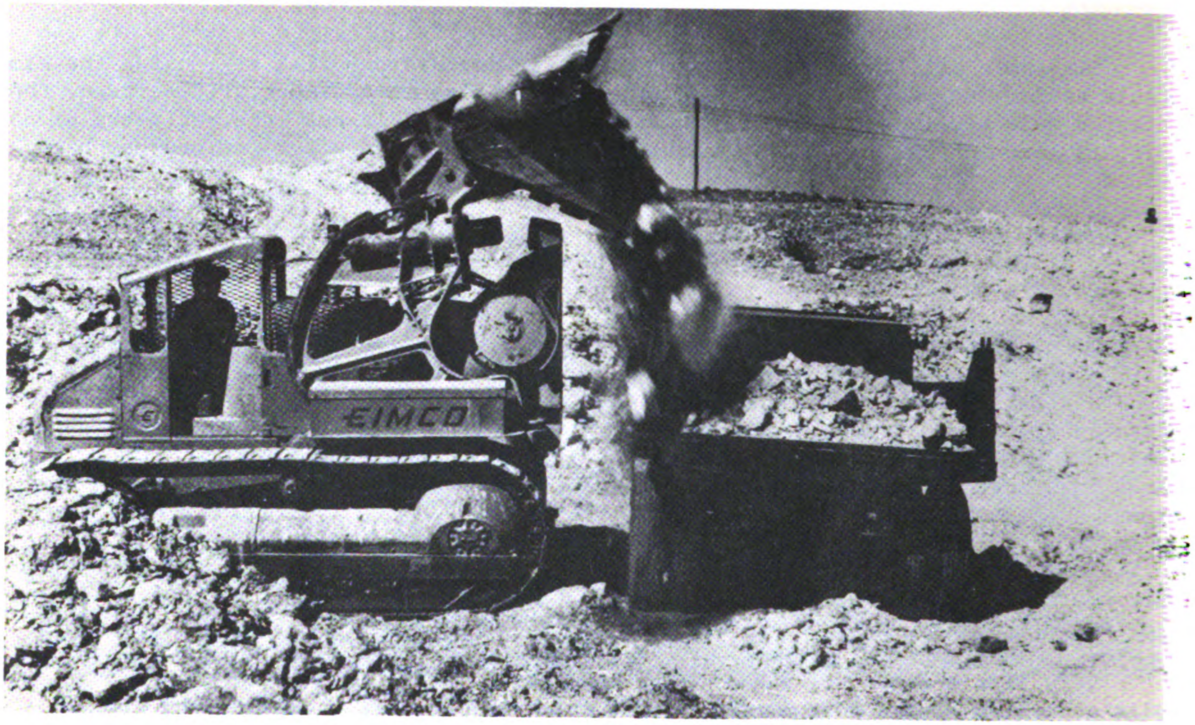

Figure 10. - Loading ore. *(Courtesy, Mining World.)*

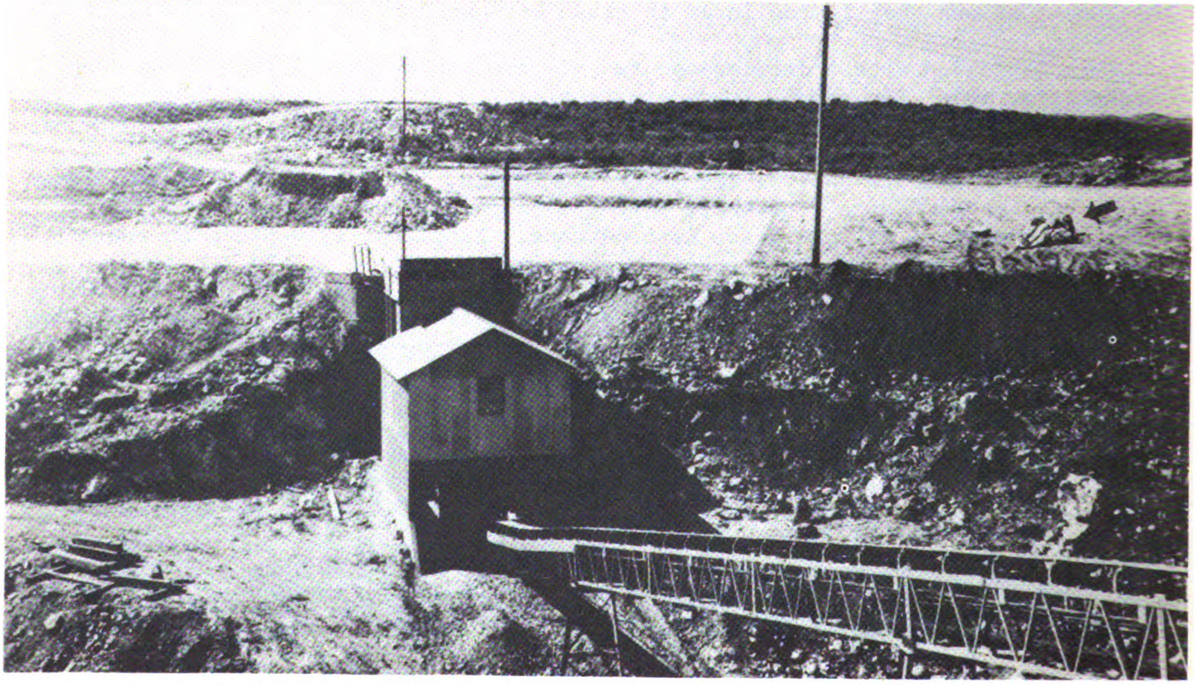

Figure 11. - Blending apron and crushing plant. Boulders at right (arrow) are oversize. *(Courtesy, Rare Metals Corporation of America.)*

TABLE 2. - Production, Rare Metals Corporation of America

(September 1955-September 1956)

Pit	Total, tons	Percent of total	Average grade	Hg, flasks	Percent of total, Hg
A	30,268	56.0	3.42	1,362.06	51.7
B	8,927	16.5	3.40	399.36	15.1
C	1/360	.7	1/3.00	14.21	.5
D	14,521	26.8	4.51	861.71	32.7
Total ..	54,076	100.0		2,637.34	100.0
Weighted average			3.71		

1/ Represents only material from old dumps.

Drainage is no problem, because the mining area is above the water table.

Crew and Cycle of Operations

Five men comprise the mine crew - the wagon-drill operator and helper, two truck drivers, and a heavy-tractor operator. Two laborers, employed as members of the plant crew, serve both mine and plant, with time charged according to work performed. All labor is paid on an hourly basis.

The general superintendent is in charge of all operations, and his time and that of the sample foreman-office manager are charged according to duties performed.

THE PLANT

General

Although many improvements in the technique of treating quicksilver ores have been and still are being made, the metallurgical treatment is basically the same now as in 400 B. C.

Briefly, cinnabar ore is crushed, then heated in the presence of air to a temperature at which moisture and water of crystallization shatter the rock and the mercury and sulfur of the cinnabar vaporize. The sulfur combines with oxygen from the air to form sulfur dioxide gas; and the quicksilver vapor, on cooling, condenses to a liquid.

At Idaho Almaden the ore is crushed in a jaw crusher and conveyed to the mill bin, from which it is fed to the oil-fired kiln. Mercury-laden vapors are removed from the primary kiln, countercurrent to the passage of ore through it. They are drawn off through a set of condenser pipes, then sent through two redwood-stave tanks, thence to the atmosphere through a redwood-stave stack.

The liquid mercury is collected in a water-sealed thickener below the condenser pipes. It is cleaned and dried in a plant-designed and -built automatic hoeing machine and filtered three times during its passage to the air-pressure bottling machine.

Calcine passes from the primary kiln to the heat-exchange kiln. Air that is heated in its passage through the heat-exchange kiln is piped to the fine-ore bin to preheat the furnace feed, and the calcine is discharged over the mountainside.

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Gordon I. Gould & Co., San Francisco, designed the 175-ton-per-day treatment plant and furnished its equipment. The plant is housed in a 140- by 50-foot steel-frame building, covered with galvanized iron, lighted and ventilated by plexolite windows and skylights.

Electric power is supplied at 440 volts by the Idaho Power & Light Co. A central-panel switchboard, with motor control and temperature and performance gages, permits one man to operate the entire plant (fig. 12).

Crushing

The 10-ton-capacity crusher hopper is kept filled directly from the trucks or from the storage apron by a front-end loader. The grade of ore can be controlled by selective loading from the various piles on the apron. Grade variations of the kiln burden have little or no effect on the percentage of mercury recovered, however, and ore is loaded from different pits so that it is of similar physical and chemical characteristics for daily or longer periods for efficient kiln operation. Grade control is determined on a weekly basis to approximate an average of 3.5 pounds per ton.

Ore enters the crusher hopper over a 10-foot-square grizzly, made of 120-pound steel rails, with 18- by 30-inch openings. Boulders too large to pass through the grizzly and too hard to be broken on it are picked out by the end loader and stacked to one side of the apron. The amount of oversize is small and has required no blasting to date.

From the crusher hopper the ore is fed by a 30-inch tapered-bar, vibrating-grizzly feeder to the 20- by 36-inch, 50-ton-per-hour-capacity jaw crusher, powered by a 50-hp. constant-speed motor. All crushing is done single-stage in a jaw crusher. Maximum 30-inch material is reduced to minus 3 inches for further processing. The ore is abrasive but shatters easily.

Approximately 50 percent of the ore is minus 3-inch that would fall on the conveyor belt, but to equalize the load on the belt the amount that passes directly to it is regulated by a movable steel plate that covers a portion of the grizzly bars.

The minus 3-inch ore is conveyed on an 18-inch, rubber-covered belt to the fine-ore bin. The conveyor is 186 feet long and inclined at an angle of 13° (fig. 13). The uncovered belt is provided with a walkway and handrail.

Furnacing

The Kiln

Ore in the fine-ore-bin is heated by hot air from the heat-exchange kiln. Its temperature depends on the weather and the rate of withdrawal. The ore is fed to the kiln by a 25-ton-per-hour, reciprocating, tube feeder (fig. 14). The rate of feed is controlled by the speed of the 15-hp., variable-speed drive motor and depends on the moisture and physical characteristics of the ore. For example, B ore contains more clay and moisture, packs readily, and is fed slower.

The rotary kiln at Idaho Almaden is reported to be the largest furnacing mercury ore in the United States, with a rated capacity of 175 tons per 24 hours (fig. 15). Actually, the furnace capacity varies for different ores; for example 175 tons

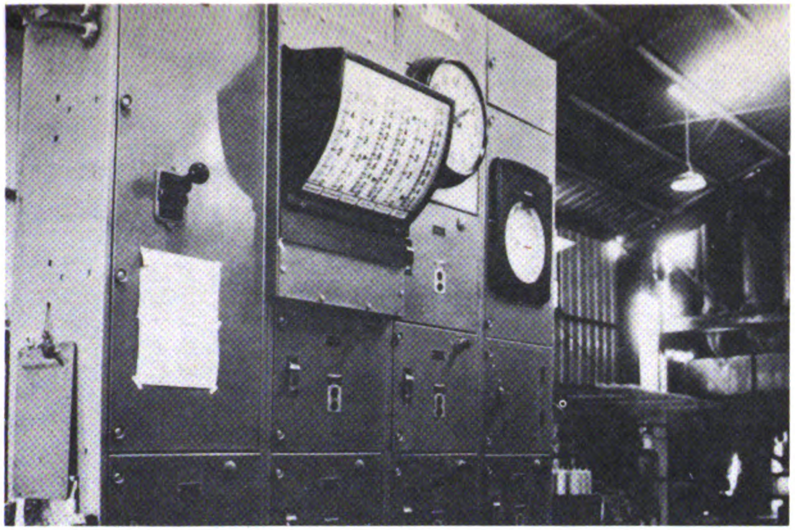

Figure 12. - Plant control panel.

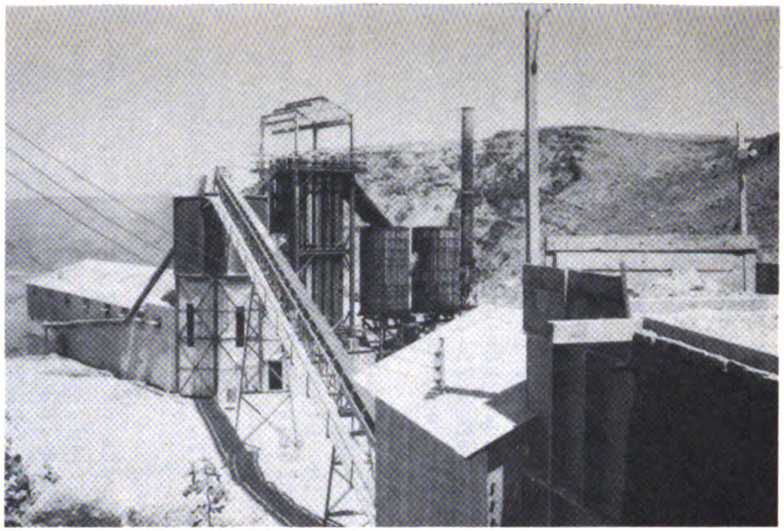

Figure 13. - Conveyor. Crushing plant to fine-ore bin.

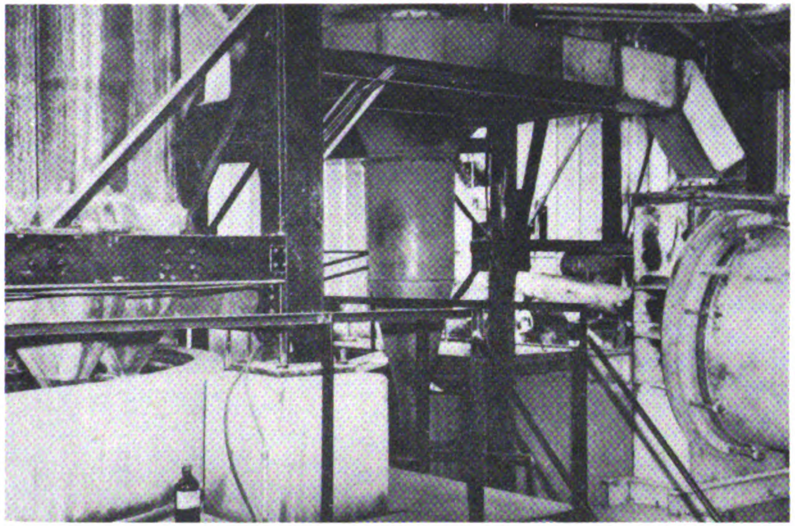

Figure 14. - Head end of plant. Lower left, thickener; center, dust collector; right, kiln feed.

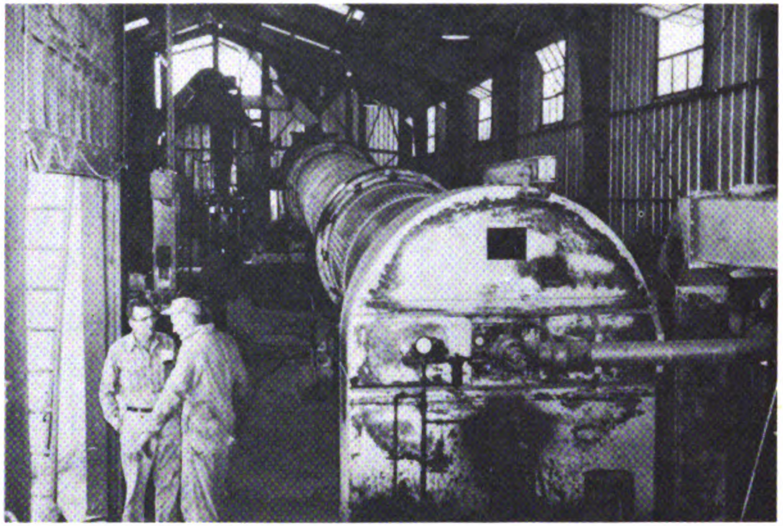

Figure 15. - Ore kiln. Heat (discharge) end in foreground.

(These pictures by Courtesy, Rare Metals Corporation of America.)

of B ore is roughly equivalent to 200 tons of D ore. The kiln is 90 feet long, with an inside diameter of 5.5 feet, and rotates at 3.5 r. p. m. It is supported by 2 ride rings set 22 feet from the ends of the kiln, and inclined on a slope of 3/4 inch to 1 foot.

The kiln is lined with 1-inch-thick sheets of asbestos between the steel shell of the kiln and the 6-inch-thick cupola firebrick lining. The brick lining is highly abrasion-resistant, and relining has been necessitated only because of spalling near the firing end. Three patching jobs have been necessary in 8 months. Such patching suspends production for 2 days; 24 hours is required to cool the kiln and 24 hours to repair the lining with plastic firebrick. When the entire firing end of the kiln is relined, the company plans to replace the first 25 feet of lining with a brick that has less wearing qualities but will not spall so readily.

A low-pressure burner, which uses about 7.5 gallon of No. 5 fuel oil per ton of feed, supplies heat for the kiln. Oil is stored 300 feet from and 40 feet above the plant in a 30,000-gallon tank (fig. 1) and flows to the plant by gravity through a 2-inch insulated pipeline. Two thermostatically controlled heaters - an immersion heater in the tank and a line heater just outside the tank - raise the temperature of the oil so that it enters the plant at a minimum of 120° F. In the plant it is pumped through a 10-kw. heater into the burner at 180° F. A low-pressure turboblower furnishes air for the burner.

Burner adjustment is necessary when different types of ore are treated. B ore, because it contains more clay, requires greater heat; but too high temperature causes high-sandstone D ore to melt, with resultant slag rings in the kiln.

Visual inspection is the only way to tell when the ore has been heated enough (fig. 16). A scoopful of burned rock is removed manually through a door in the firing end of the kiln; a dull, cherry-red color indicates when treatment is adequate. During normal operations this is done hourly when the calcine is sampled. More frequent inspections are made during startups of the plant and when the feed is being changed. Discharge temperature from the hot kiln is 1,200° to 1,400° F. It takes an average of 45 minutes for ore to pass through the kiln.

Adjacent to the plant fuel-storage tank and piped into its discharge line is a 1,000-gallon tank containing diesel oil. Before each plant shutdown, the line from the tank to the plant is filled with the lighter diesel oil to protect the fluidity of the fuel in the line.

Mercury Collection

Mercury-laden vapors at 450° F. are drawn out of the kiln and through a cyclone dust collector by a 48-inch, hot exhaust fan, controlled by a 15-hp., variable-speed motor (fig. 14). The cyclone discharges dust into a dust pot, where water from the settling tank is added to form a waste slurry.

The partially cleaned vapor is passed through a manifold to the condenser system (fig. 17). Four circuits of 19 pipes each comprise the system. In each circuit 18 pipes are joined in pairs to make 9 vertical sections. The upper ends are connected in series by U-bends with cleanout disks (fig. 18); the 19th pipe connects the circuit with the first of two 12-foot-diameter by 20-foot-high, redwood-stave scavenger tanks. The bottom ends of the vertical sections also are joined in series by a Y-discharge connection, the open lower outlet of which is water-sealed in the thickener (fig. 19).

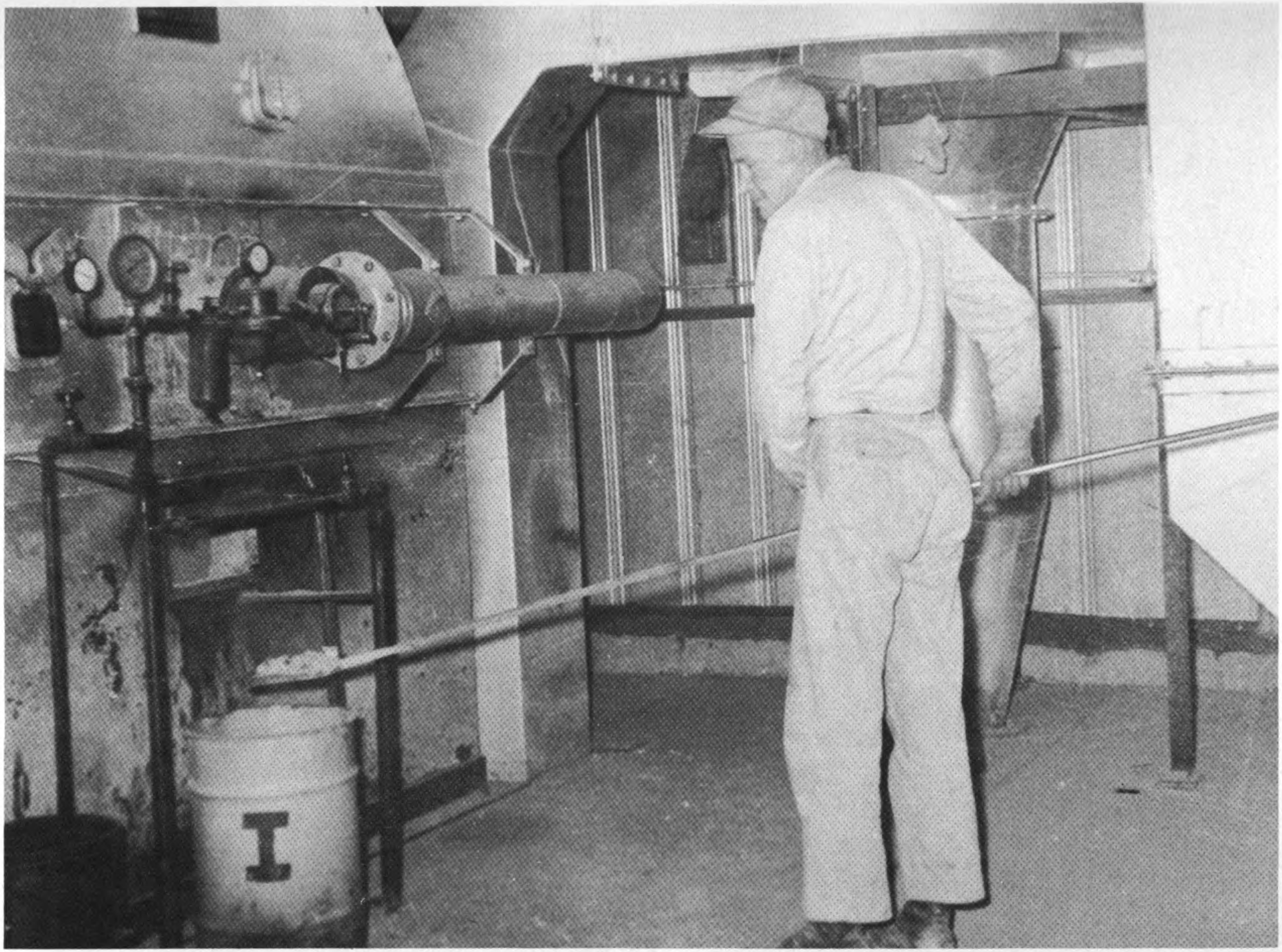

Figure 16. - Sampling and inspecting calcine.

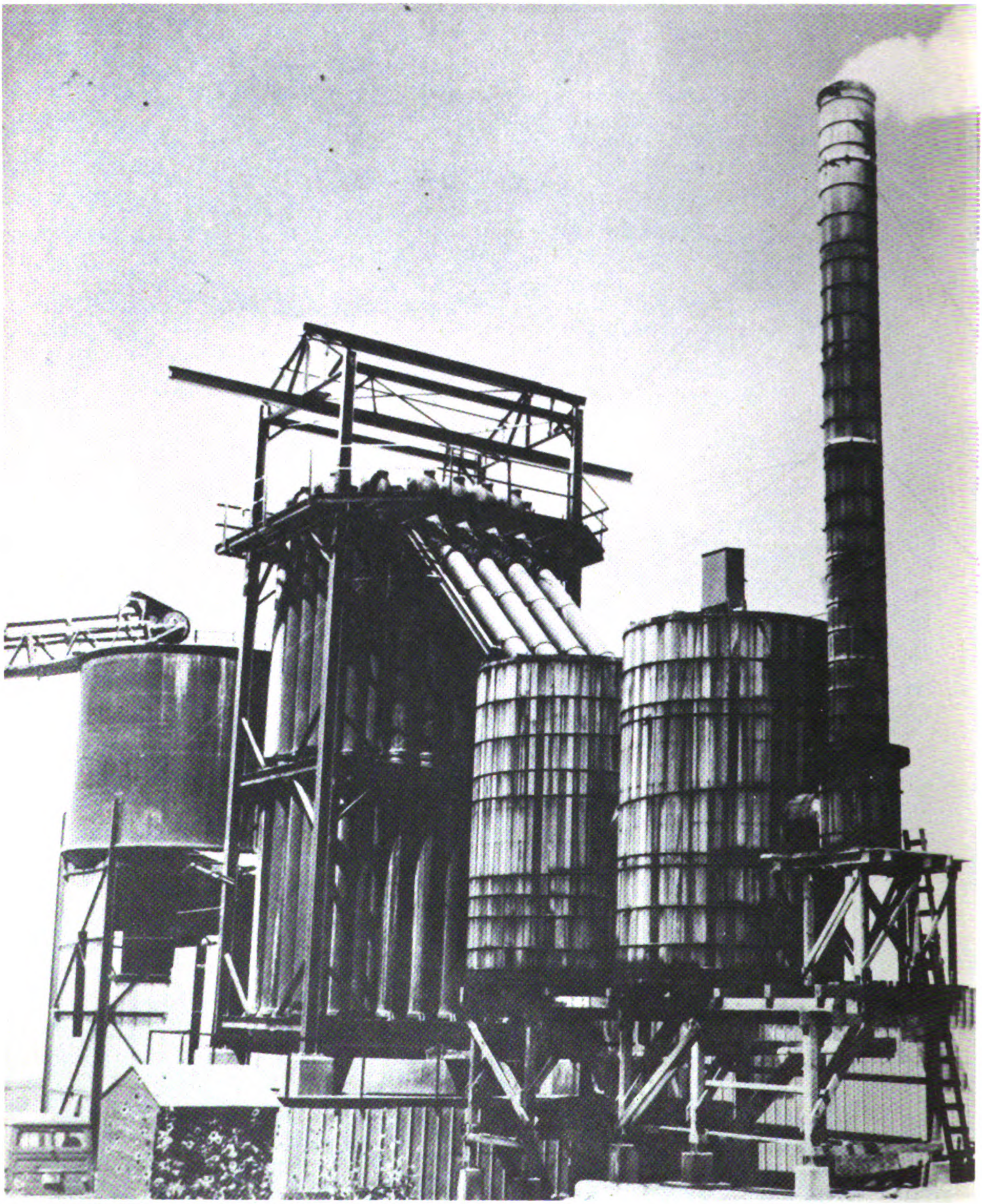

Figure 17. - Condenser system. Fine-ore bin at left.
(Courtesy, Rare Metals Corporation of America.)

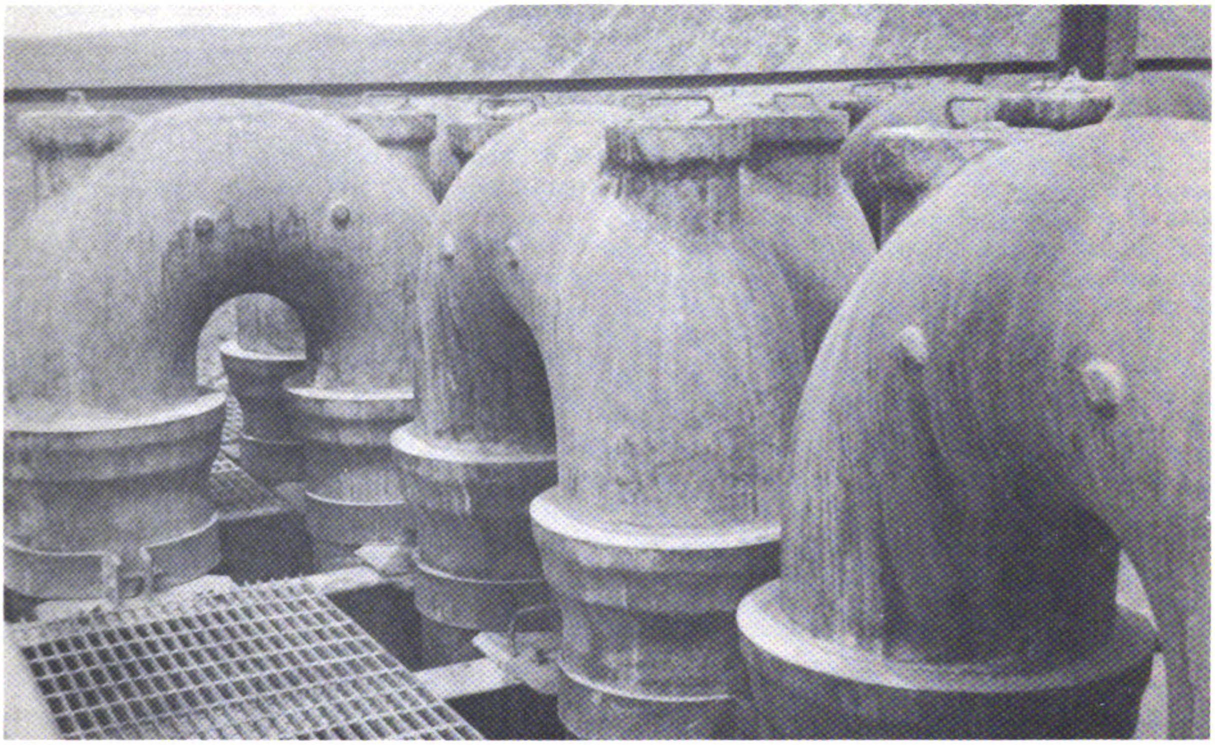

Figure 18. - Condenser-pipe U-bends. Note clean-out discs.

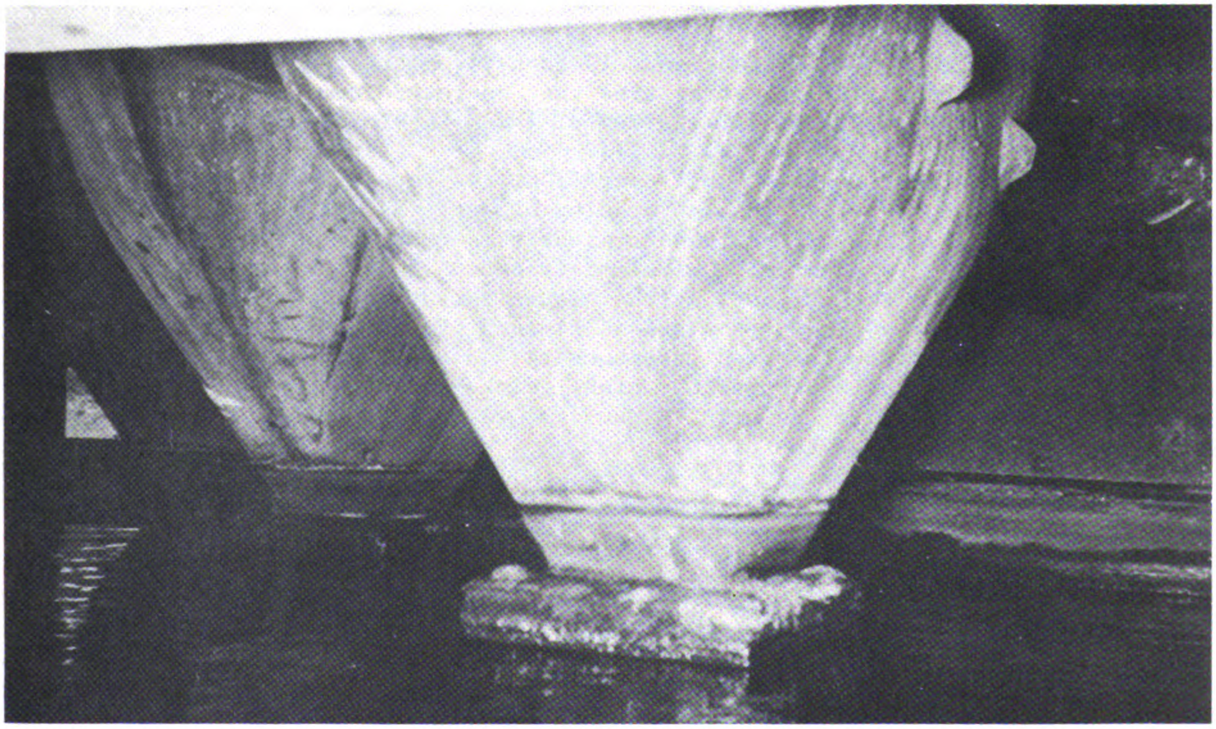

Figure 19. - Condenser-pipe discharge, showing water seal in thickener.

As the vapor condenses, the bulk of the mercury, plus soot, adheres to the inside of the pipes. Condenser pipes are washed down on alternate days. A rake mechanism in the 18-foot-diameter by 18-inch-deep thickener settles the mercury and mud and rakes it into 2 collection pots from which it is fed to the hoeing machine.

The first redwood tank contains a series of wooden latticework baffles. Water is sprayed over the network, so there is a continuous drip within the tank. This cools the expanding gases approximately 25° and causes condensation of almost all remaining mercury; both tanks are washed down every 10 to 14 days. Discharge from the redwood tanks is water-sealed into rubber buckets set in a riffled launder below the tanks.

The launder flow, containing dust particles with some mercury adhering to them, can be directed either to the thickener or to a wooden settling tank. When the riffles are being cleaned, the flow is directed to the thickener; otherwise it and the thickener overflow go to the settling tank. Lime is added to flocculate the fine suspended colloidal muds and produce a clear water overflow, which is sent to waste.

The wooden tank is cleaned only when full (every 3 or 4 months), and the product has assayed as high as 190 pounds of mercury per ton. To add this material to the kiln, quick-setting cement is added and the resulting solid is broken into pieces. In the kiln the mercury is volatilized, but the cake containing soot and dirt is discharged with the calcine.

Gases pass from the scavenger tanks to the atmosphere through a 28-inch-diameter by 40-foot-high redwood stack. The company estimates that 3,400 c. f. m. of vapor enters the condenser system. Gases leave the stack at 85° to 120° F., depending on the weather; wind affects the gas-discharge temperature more than does outdoor temperature. Stack loss is considered negligible when the stack temperature is held at or below 120° F.

Originally, mercury was cleaned on a 10-foot-diameter steam-heated hoeing table, set below the thickener, with rotating arms that operated from the same shaft as the thickener. Cleaning was slow, and much manual labor was involved.

To improve the efficiency of this operation, a 2-foot-diameter by 2-foot-deep automatic hoeing machine, with double rotating blades, was designed and built by plant personnel (fig. 20). The thickener product is drawn from the collection pots through a pipe into this machine. Quicklime is added in approximately the ratio of 2 pounds per ton of kiln feed; and, as the blades agitate the material, the cleaned mercury is discharged by gravity through a 3/4-inch pipe to a 17-1/2-bottle-capacity mercury sump. The residue is raked into buckets and added manually to the kiln feeder; when the dirt ratio becomes too high, quick-setting cement is added. The resulting solid is added to the kiln in the same way as the settling-tank mud, which eliminates excess dirt from the circuit.

From the sump the mercury is forced by air pressure into a surge tank of 100-bottle capacity (fig. 21). During its passage from the hoeing machine to the bottling tank, the mercury is filtered through screen, ceramic, and chamois filters. From the surge tank it is drawn into a 1-flask volumetric container, and the bottles are filled by gravity.

The floor of the plant is washed daily, and the washdown material runs to a sump outside the plant; when the sump is cleaned each month, an average of 1 flask of mercury is obtained from the washdown material.

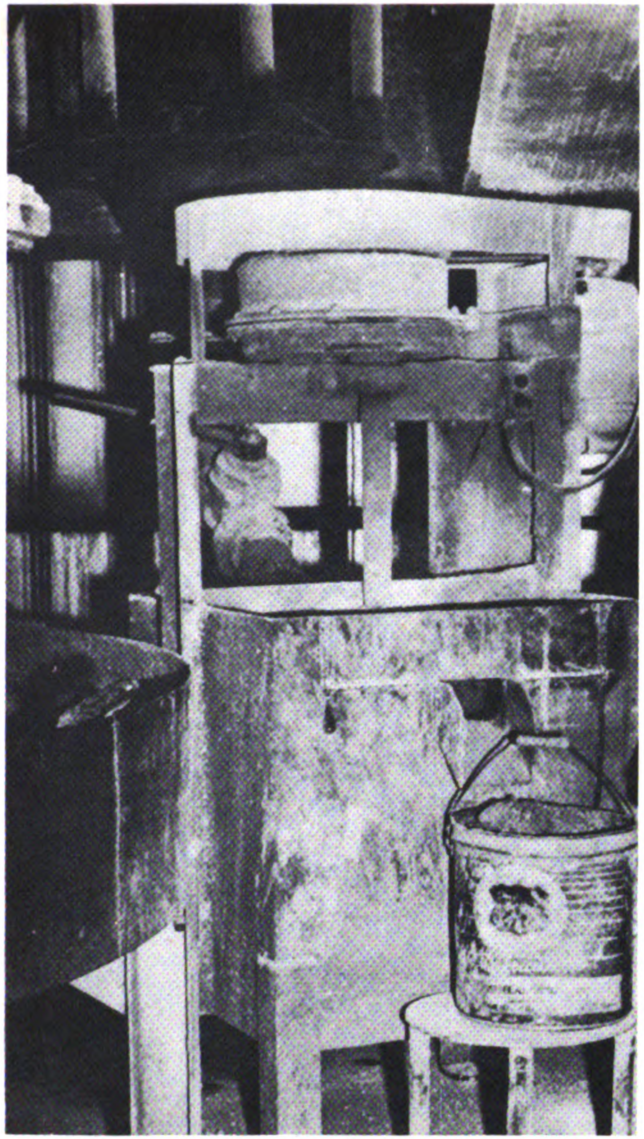

Figure 20. - Automatic hoeing machine. Collection pot upper left.

(*Courtesy, Rare Metals Corporation of America.*)

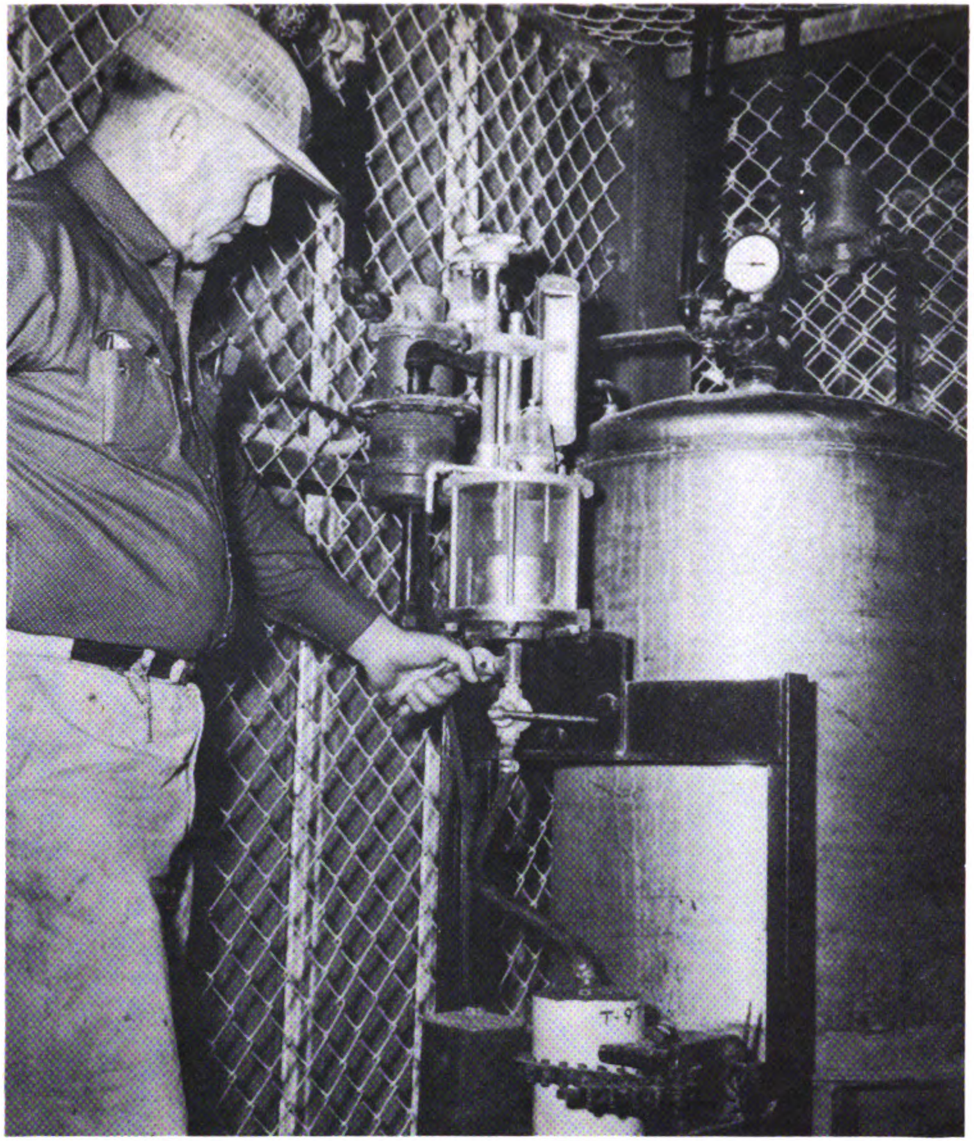

Figure 21. - Bottling mercury. Surge tank in background, volumetric tank half full.

(*Courtesy, Rare Metals Corporation of America.*)

Waste Treatment

Burned ore is discharged through a firebrick-lined chute into a 40-foot-long by 6-foot-diameter auxiliary cooler kiln with baffles, set on a 1/2-inch to 1-foot slope below the main floor of the plant. A cooler-intake fan draws outside air into the kiln, cooling the calcine and heating the air to approximately 600° F. The heated air is drawn through a cyclone into an 18-inch pipe to the fine-ore bin (fig. 22).

The temperature of calcine discharged from the heat-exchange kiln varies from 200° to 300° F., depending on the weather. After the calcine leaves the auxiliary kiln, it piles on a ledge 20 feet below the plant. Later, the ledge is cleaned with the end loader, and the calcine is pushed down the side of the mountain and left there.

Crew and Cycle of Operations

Nine men comprise the plant crew: 1 master mechanic, 4 kiln operators, 2 utility men, and 2 laborers. The schedule of kiln operators is arranged so that the plant is operated continuously. An applicable portion of time of the two laborers is charged to the mine.

Four hours of crushing during the day shift furnishes a 24-hour supply of plant feed. When the day shift begins, ore is crushed until the fine-ore bin is filled, which usually requires about 3 hours. During the last hour of the day shift the crusher is operated again until the fine-ore bin is filled. When the crusher is idle, the crusher feeder helps the assayer.

Rotating the work schedules of personnel for safety purposes is discussed under Safety Measures.

Marketing

Mercury is bottled daily; the major portion of the production is handled on days when the condenser pipes are washed down. Grade tests are made by taking composite samples of 2 drops from each of 25 flasks at the bottling machine. The average grade of all mercury shipped is 99.998 percent.

Bottled mercury is sent by truck to Weiser and shipped from there by auto freight to the eastern market. Under contract, a chemical company is obligated to purchase 200 flasks per month, and any excess must be offered to it before being sold on the open market.

All mercury is sold as Prime Virgin grade or a minimum of 99.9 percent mercury. The sale price is based on the monthly average of the preceding month in E & M J Metal and Mineral Markets.

SAFETY PRACTICES

Industrial

The company has an enviable safety record. In its safety program the company anticipates possible causes of accidents and takes all possible preventive measures. Safety suggestions of the State mine inspector are complied with at all times.

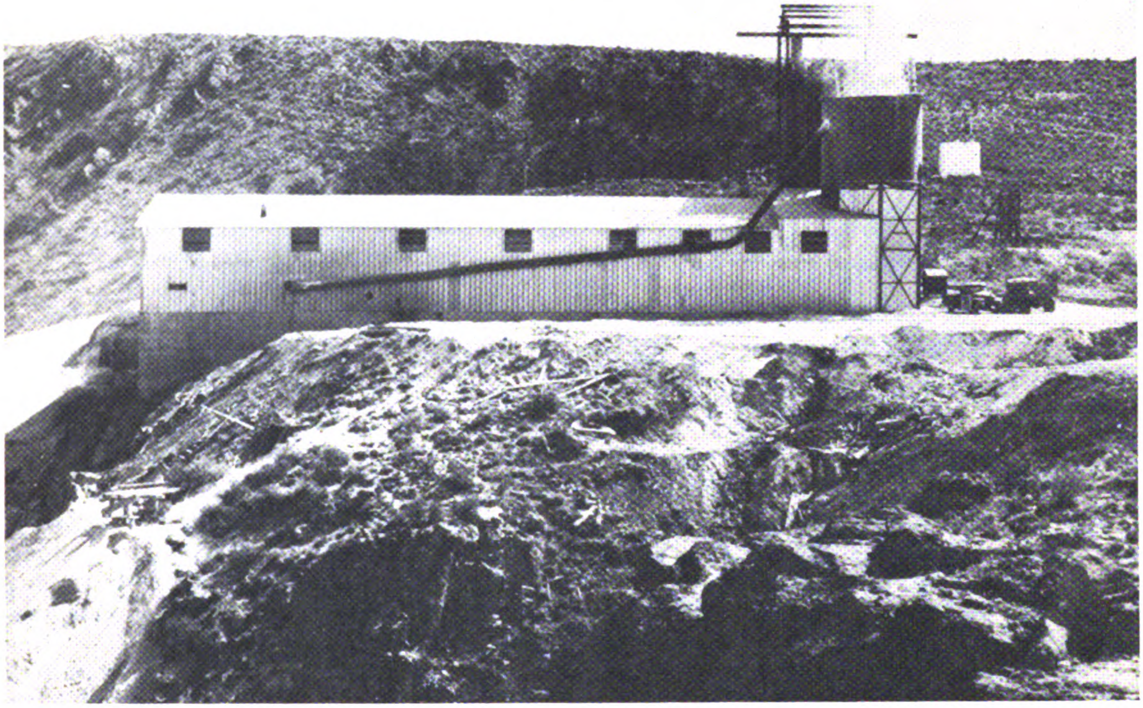

Figure 22. - Preheating ore. Large pipe conveys heated air from heat-exchange kiln to fine-ore bin. *(Courtesy, Rare Metals Corporation of America.)*

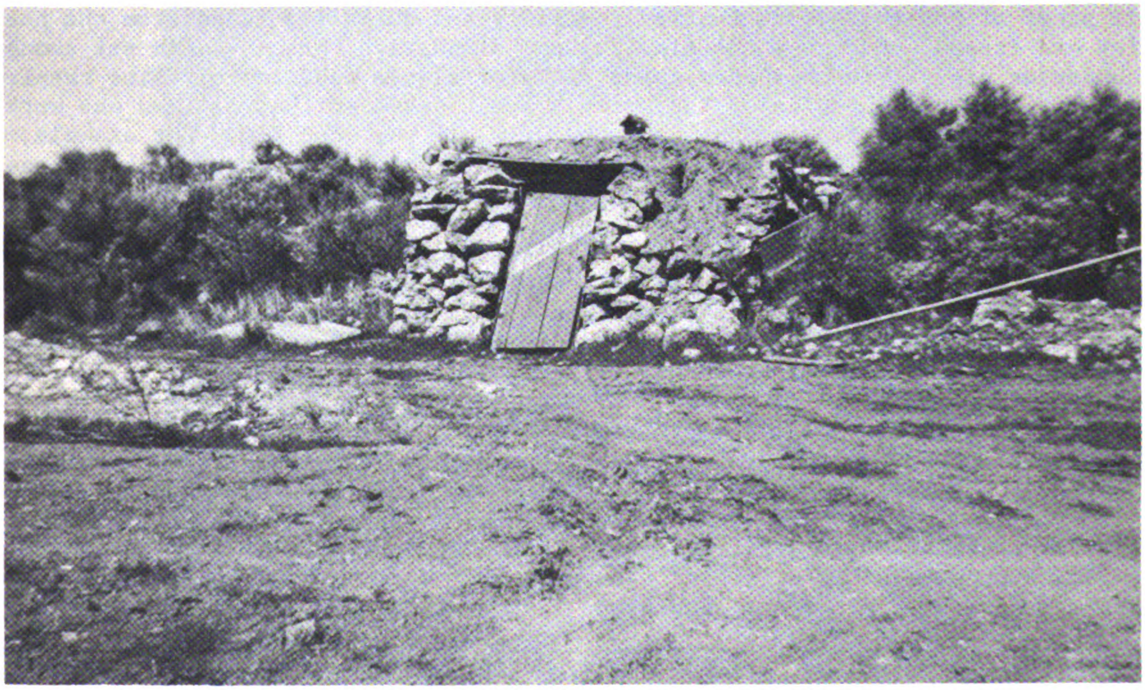

Figure 23. - Explosives magazine.

In the plant all drives and belts are guarded; and the company furnishes goggles, gloves, and both dust and air-line respirators. Goggles at certain operations are mandatory. A minimum of two men is employed on each shift.

Explosives are stored in 2 magazines; 1 holds 10 tons of powder, the other blasting caps. Both magazines, separated by a half mile, are rehabilitated adits with bulletproof, stormproof doors; they are floored, frostproof, and dry (fig. 23).

Mercury Poisoning

In addition to accident prevention safety practices include precautions to avoid salivation (the word commonly used for any form of mercury poisoning).

Mercury enters the body through the skin by exposure to dust, through the respiratory tract by inhalation of dust and vapor, and through the alimentary canal by swallowing particles from contaminated articles and substances taken into the mouth.[7] Poisoning can be acquired in mining native quicksilver, in the reduction of mercury ores, and in handling mercury and mercury compounds in industry and research.

The symptoms and effects vary from chronic cases caused by exposure to minor amounts over a long period of time to acute cases resulting from exposure to large amounts of fumes, dust, or soot. Providing proper ventilation, avoiding hazards, and observing personal cleanliness are recognized as the best preventive measures.

At Idaho Almaden the outstanding precautionary measure in mining is personal cleanliness. No native quicksilver is found on the property, and open-pit mining provides excellent ventilation of the working faces; poisoning from handling cinnabar is possible, however, by smoking and inhaling fumes of roasted particles.

In the plant all dangerous practices are eliminated, and workmen are protected in all areas of possible contamination. Mercury and quicklime fumes from the hoeing machine are trapped under a hood (fig. 24) and discharged through a fan set among the condenser pipes. The hoeing machine operator always wears an air-line respirator (fig. 25). The schedules of the workmen are rotated so that all men who work in places where contamination is possible spend time in the open air. For example, a hoeing-machine operator spends no more than 30 days on this work before being replaced to drive a truck, operate the drill rig, or perform another outdoor job.

At the feed end of the kiln the opening is covered tightly where the feed mechanism passes through the mercury-vapor discharge flue. Many materials were tried, but they deteriorated rapidly because of heat. The most successful and least expensive covering used to date is an opened piece of tire inner tubing, tied securely to both the feeder and the flue opening (fig. 26).

Personal cleanliness is facilitated by the combined showerroom, changeroom, and washroom. Hot water is plentiful, and the washroom has facilities for washing work clothes. Daily washdown of the floor eliminates additional hazards.

To detect immediately any trace of incipient mercury poisoning, a physician, at company expense, checks all plant indoor workmen every month and outdoor workmen every 3 months - oftener if any suspicious symptom is noted. No case tested has

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[7] Davenport, Sara J., and Harrington, D., Mercury Poisoning as a Mining Hazard: Bureau of Mines Inf. Circ. 7180, 1941, 27 pp.

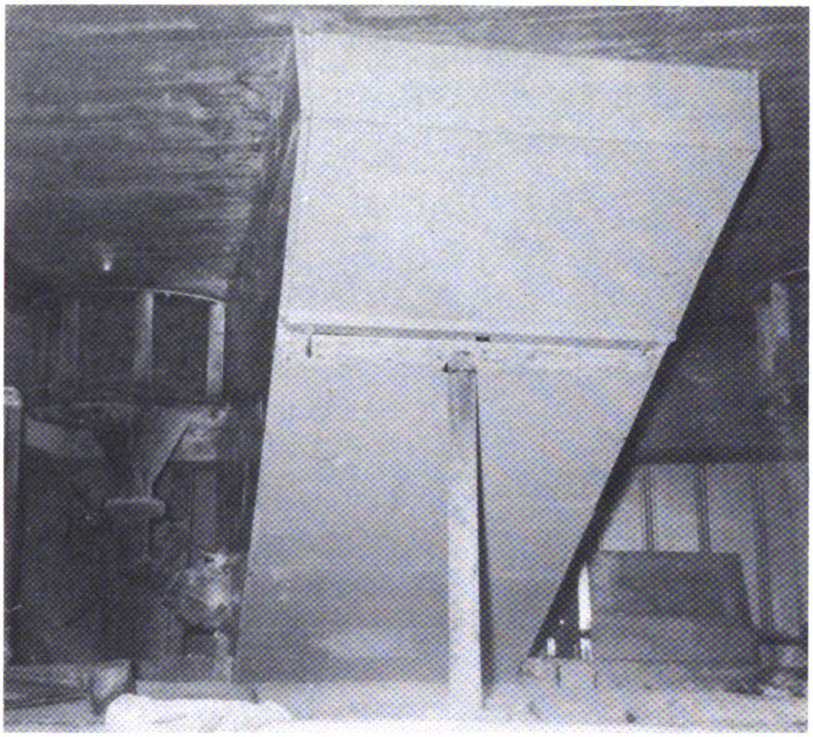

Figure 24. - Hoeing-table hood.

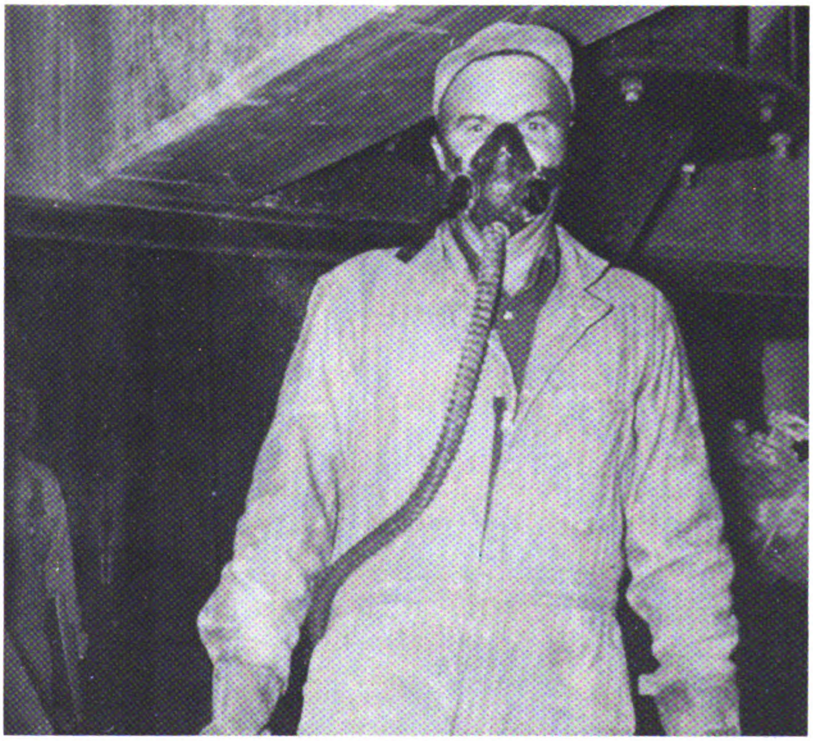

Figure 25. - Hoeing-machine operator, wearing air-line respirator.

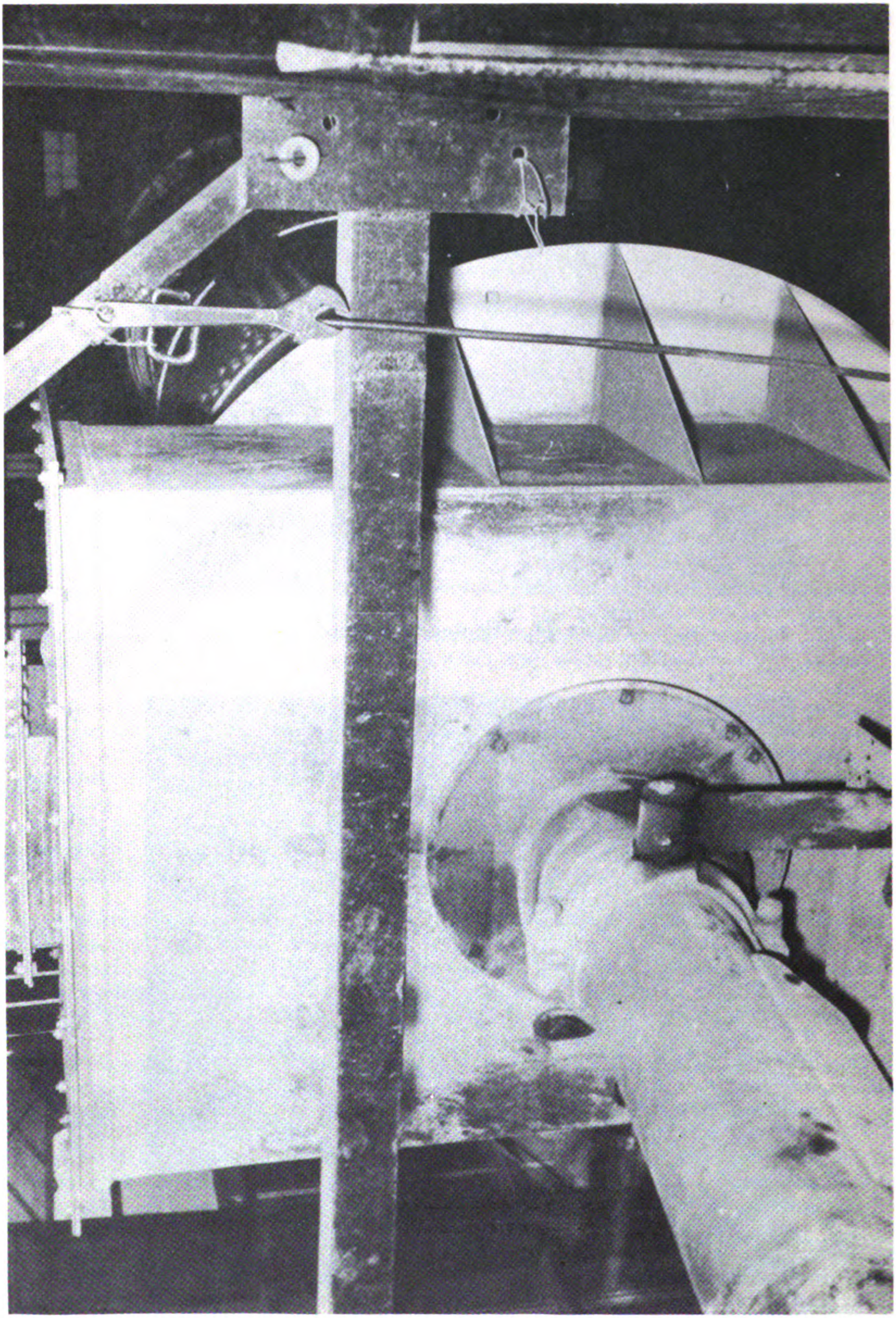

Figure 26. - Dust guard, kiln feed.

shown absorption of more than 10 percent of the maximum allowable by State safety standards. Any workman who shows even a trace of poisoning is immediately transferred to an outdoor job until he has passed a negative test.

Preventive guards, careful observance of safety practices, and rotating the schedules of the workmen are credited with the commendable record of this company.

Fire Protection

Water for fire protection and plant use is pumped from a spring near the foot of the mountain through a 1-1/2-inch line by a 20-g. p. m. positive-displacement pump at 400 pounds pressure against a 670-foot head. The pump runs continuously and is checked daily and serviced weekly.

Three hydrants, complete with hoses and nozzles, are connected by a 3-inch line to a 50,000-gallon water-storage tank and furnish ample protection for the plant and the crusher. A hydrant with a 1-inch line and accessories protects the office.

COSTS

Mining and treatment costs and labor efficiency (tables 3, 4, 5, and 6) are given for two consecutive periods - the last quarter of 1955 when the plant was being broken in and the first quarter of 1956 when operations had become standardized. During these periods tonnages mined and treated are about equal.

All labor costs include industrial and unemployment compensation, social security, and taxes dependent on labor charges.

Fire protection, drinking water, medical examinations, and positive-pressure respirators are included in tables under Welfare, medical and safety.

Miscellaneous mining charges include ramps and pit approaches, equipment maintenance, and freight. Miscellaneous treatment charges comprise pumping, pump maintenance, and water service; freight; hauling mercury to market; surface improvements; communications system; changehouse; oil, grease, and shop equipment; and labor for access-road maintenance.

The slight rise in mining costs in the second period reflects an increased cost for development. During the first period development cost was lower than normal, because initial contract stripping was omitted. The actual mining cost during period 2 decreased slightly.

Concentration (the highest cost item) includes furnacing, settling, and hoeing. Concentrator maintenance includes, as its major expense, patching the heat end of the kiln lining; when the anticipated change in type of lining is made, the cost is expected to be lower. Except for tailings disposal, treatment costs decreased in the second period.

A decrease in overall cost for the second period is largely attributed to equipment having been broken in, the plant "bugged out", and procedures standardized. Continuing improvements in efficiency and recovery may well decrease the cost per unit.

Cost per ton during the second period was: Mining, \$1.05; treatment, \$2.61; total, \$3.66. Of the total, 36 percent was labor and 64 percent supplies.

TABLE 3. - Costs

(Per 100 tons)

	Period 1[1]			Period 2[2]		
	(14,695 tons, as mined)			(14,917 tons, as mined)		
	Labor	Supplies	Total	Labor	Supplies	Total
Development:						
Stripping[3]	$2.43	$2.90		$2.61	$8.13	
Drilling	.29	.42		1.23	.92	
Sampling and assaying	1.10	.09				
Subtotal	3.82	3.41	$7.23	3.84	9.05	$12.89
Mining:						
Direct mining:						
Drilling	9.67	3.23		4.23	6.80	
Blasting	3.11	9.98		5.08	9.29	
Loading	6.36	11.34		4.08	12.60	
Hauling	11.42	7.60		8.03	10.13	
Sampling and assaying	4.74	1.89		2.29	2.62	
Miscellaneous	9.38	1.04		2.31	3.85	
Subtotal	44.68	35.08	79.76	26.02	45.29	71.31
Indirect mining:						
Supervision and engineering.	8.05	.02		10.33	.58	
Office	1.49	.44		2.44	1.09	
Welfare, medical and safety.	.43	.74			.62	
Miscellaneous	1.56	2.48		1.33	4.25	
Subtotal	11.53	3.68	15.21	14.10	6.54	20.64
Total	60.03	42.17	102.20	43.96	60.88	104.84

	Period 1[1]			Period 2[2]		
	(14,138 tons treated)			(14,668 tons treated)		
	Labor	Supplies	Total	Labor	Supplies	Total
Treatment:						
Direct costs:						
Crushing	$9.51	$4.57		$7.05	$3.56	
Sampling and assaying	7.14	2.32		4.91	2.61	
Concentration	47.90	101.67		41.45	93.68	
Concentrator maintenance	24.85	19.57		14.33	6.21	
Reagents		3.28			1.93	
Tailings disposal	.06	1.91		.32	.54	
Power		12.73			8.14	
General maintenance	6.17	13.73		1.43	7.18	
Miscellaneous	.39	7.40			4.31	
Subtotal	96.02	167.18	$263.20	69.49	128.16	$197.65
Indirect costs:						
Supervision and engineering.	25.74	0.07		12.14	0.40	
Office	5.11	3.18		2.49	3.58	
Welfare, medical and safety	1.35	4.70			2.74	
Miscellaneous	7.11	12.73		2.89	38.85	
Subtotal	39.31	20.68	59.99	17.52	45.57	63.09
Total	135.33	187.86	323.19	87.01	173.73	260.74
Total mining and treatment	195.36	230.03	425.39	130.97	234.61	365.58

[1] 4th quarter, 1955.

[2] 1st quarter, 1956.

[3] Does not include preliminary contract stripping.

TABLE 4. - Costs

(Percent of total)

	Period 1[1/]		Period 2[2/]	
	Labor	Supplies	Labor	Supplies
Development	52.8	47.2	29.8	70.2
Mining:				
Direct	56.0	44.0	36.5	63.5
Indirect	75.8	24.2	68.3	31.7
Total, mining	58.7	41.3	41.9	58.1
Treatment:				
Direct	36.5	63.5	35.2	64.8
Indirect	65.5	34.5	27.8	72.2
Total, treatment	41.9	58.1	33.4	66.6
Total, mining and treatment	45.9	54.1	35.8	64.2

1/ 4th quarter, 1955.
2/ 1st quarter, 1956.

TABLE 5. - Summary of costs in units of labor, power, and supplies

	Period 1[1/]	Period 2[2/]
A. Labor (man-hours/100 tons):		
Development	1.20	1.84
Mining:		
Drilling	3.13	2.56
Blasting	.65	1.63
Loading	2.10	2.14
Hauling	4.39	4.86
Sample and assay	1.93	1.47
Office	.83	1.08
Miscellaneous	.69	1.63
Treatment:		
Crushing	4.05	4.23
Concentration	19.44	24.05
Concentrator maintenance	9.24	7.71
Sample and assay	2.22	1.98
Office	.87	1.10
Miscellaneous	1.35	2.25
B. Power and supplies:		
Explosives ... lb./ton	.38	.21
Power ... kw.-hr./ton	8.94	10.36
Other supplies (percent of total supplies and power):		
Mining	85.0	94.0
Treatment	93.3	95.3
Overall	91.7	95.0
Supplies and power (percent of total cost)	54.0	64.0

1/ Production: Period 1 (4th quarter, 1955): 14,695 tons mined, 14,138 tons treated.
2/ Production: Period 2 (1st quarter, 1956): 14,917 tons mined, 14,668 tons treated.

TABLE 6. - Labor efficiency

(tons/man-shift)

	Period 1[1/]	Period 2[2/]
Mining	53.6	46.5
Treatment	21.5	19.4
Overall	15.8	13.8

1/ 4th quarter, 1955.
2/ 1st quarter, 1956.

APPENDIX

Pertinent Data

MINING EQUIPMENT

Item	Size	Make	Remarks
Track loader	2 cu. yd.	Eimco	Overhead.
Wheel loader	1 cu. yd.	Michigan	Front end.
Trucks	2 tons	Chevrolet	4-yd. dump beds.
Self-contained drill unit:			
Wagon drill	4-in.	G-D RMB	Chain feed.
Compressor	320 c. f. m.	Jaeger	
Motor	UD-18	International	Diesel.
Half track		do.	Government surplus.
FURNACING-PLANT EQUIPMENT			
Fine-ore bin	300 tons	Hammond Iron Works.	Cylindrical, metal.
Kiln feeder	25 tons/hr.	Gould	Reciprocating tube.
Motor	15 hp.	Sterling Speed-Trol	Variable speed.
Ore kiln	5.5-ft. diameter by 90 ft. long.	Gould	Cylindrical, 2 ride rings, 22 feet from ends.
Motor	10 hp.	Westinghouse	
Burner	1 g. p. m.	Hawk	Low pressure.
Turboblower		Spencer	
Motor	10 hp.	Westinghouse	
Vapor duct	16 by 16 in.		1/8-in. steel.
Cyclone (mercury vapor)	Size 16	American	
Fan	48 in.	do.	
Motor	15 hp.	Sterling Speed-Trol	Variable speed.
Condenser system	18-in. diameter.	Gould	76 cast-iron pipes.
Tanks (2)	12-ft. diameter by 20 ft. long.	do.	Cylindrical, redwood.
Stack	28-in. diameter by 40 ft. long.	do.	Do.
Thickener	18-ft. diameter by 18 in. deep.	do.	Concrete shell, 1 set stainless-steel arms.
Motor	1 hp.		
Hoeing table	2 cu. ft./batch.	Plant designed and built	Double blade, rectangular.
Motor	5 hp.	Sterling	
Heat-exchange kiln	6-ft. diameter by 45 ft. long.	Gould	Cylindrical.
Motor	10 hp.	Westinghouse	
Cyclone (heated air)	Size 16	American	
Fan	48 in.	do.	
Motor	2 hp.	Sterling	Constant speed.
Pump	20 g. p. m.	Deming	Positive displacement.

CRUSHING-PLANT EQUIPMENT

Item	Size	Make	Size of discharge, in.	Remarks
Hopper grizzly	10 by 10 ft.		30 (maximum)	120-lb. steel rails.
Crusher hopper	10 tons			
Vibrating-grizzly feeder		Syntron	-3	Vibrating, magnetic action, tapered bar.
Crusher	20 by 36 in.	Kue-Ken	-3	Simplex, jaw.
Motor	50 hp.	Westinghouse.		Constant speed.
Conveyor	18 in. wide by 186 ft. long.			13° angle.
Motor	5 hp.	Westinghouse.		

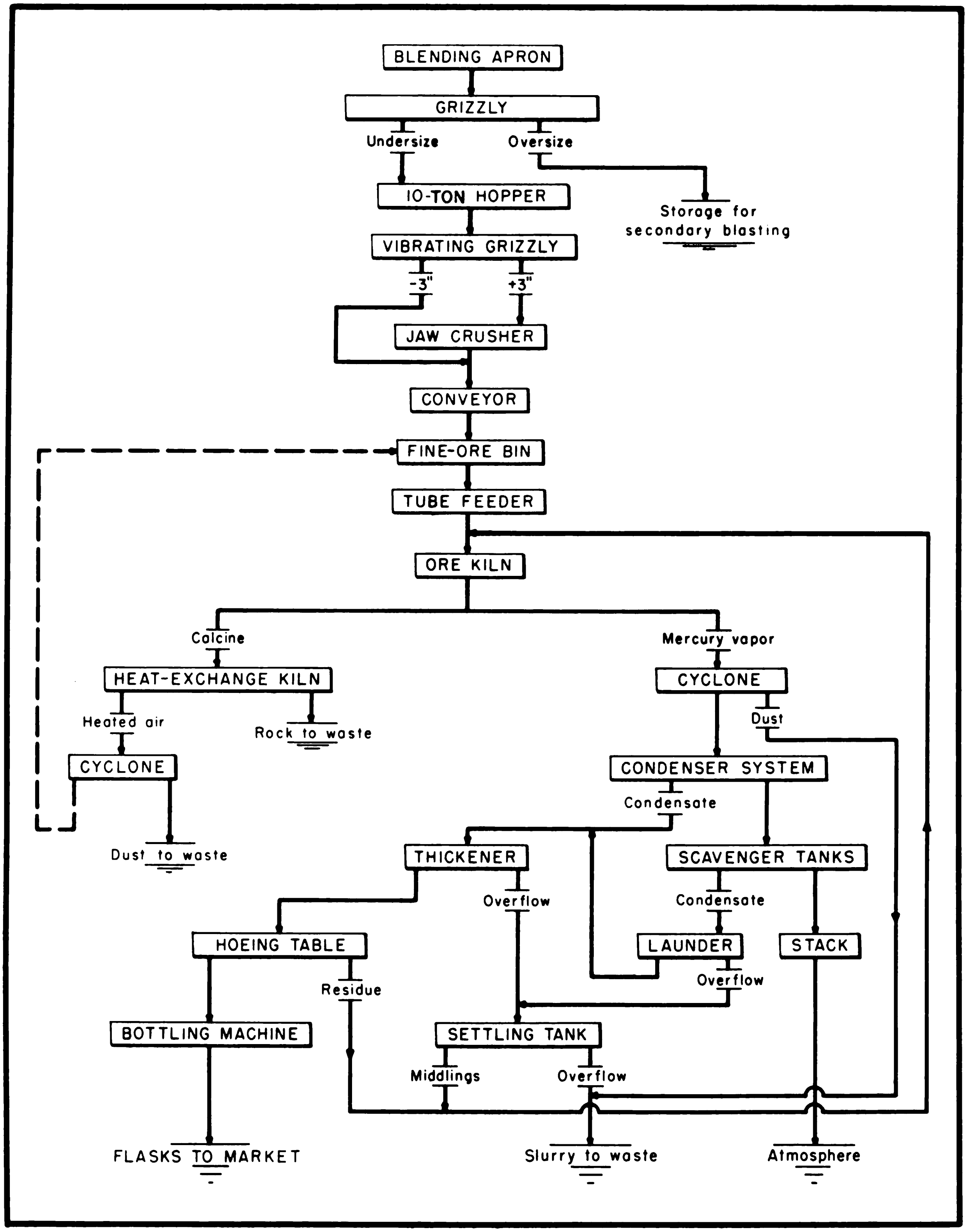

Figure 27. - Flowsheet, Idaho Almaden mercury plant.

INT.-BU.OF MINES,PGH.,PA. 8594

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